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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1920

THE POEM OF THE PHILOSOPHER THEOPHRASTOS UPON THE SACRED ART: A METRICAL TRANSLATION WITH COMMENTS UPON THE HISTORY OF ALCHEMY

By Dr. C. A. BROWNE

NEW YORK CITY

AMONG the remains of Greek literature that have come down from the Byzantine period are four poems in iambic verse upon the divine or sacred art. These poems, in the fifteen or more manuscripts which are preserved in different libraries of Europe, form part of a large collection of works upon alchemy. Most of the prose manuscripts of this collection were edited and translated by the French chemist Berthelot in 1888. The four poems, although a part of Berthelot's original plan, were not included in his edition of the Greek alchemists and, except for a meager summary of their contents by Reinesius in 1634 and a few brief extracts by Hoefer in his "Histoire de la Chimie" in 1866, no efforts have been made to give a rendering of their contents in any modern language. A study of these poems has recently been made by the writer and as they throw considerable light upon the history of Greek science in its later days, the following commentary and translation of the poem of Theophrastos are given.

The four poems, which appear in the different collections under the names of Heliodoros, Theophrastos, Hierotheos and Archelaos, usually in the order given, resemble one another so much in peculiarities of language and meter that they were undoubtedly composed under similar influences. The resemblances are so striking that Reinesius regarded the poems as the work of a single author and as nothing more than versification of different parts of the long prose work of Stephanos, who wrote in the reign of Emperor Heraclius (610 to 641 A.D.). The imitations of Stephanos in style and language are unmis-

takable and the poems must have been composed after his time. The earliest collection of the poems, the Codex 299, in the library of St. Mark at Venice, is written in a hand of the eleventh century. This codex refers again to a still earlier collection that is lost. Without discussing further the interesting questions of authorship, we are probably safe in saying that the poem of Theophrastos was composed by a Byzantine sophist or schoolman some time between the years 700 and 900 A.D. All four poems, in fact, celebrate the importance and learning of these sophists, which term in the days of the Greek Empire was one of honor and not of reproach. Theophrastos[1] begins his poem with the following eulogy:

> We sophists, and the rhetoricians too,
> Are fortunate and lead a life most wise;
> We know the nature of created things,
> The kinds of elements, and understand
> How, by close union each to each, they tend
> To one new form, most fair and wholly strange,
> With brilliant splendor filled, its make-up such
> That it bestoweth wealth and great reward.

The union of the elements into a new wealth-bringing combination has always been the one great aim of alchemy. Theophrastos, however, in order to dispel the belief that he and his fellow sophists were only worshipers of mammon, hastens to add that their chief object in life was to train new converts in the path of wisdom.

> But most of all we wish with one accord
> All mortals to be taught and disciplined
> And trained in wisdom of the sophist school,
> That they may shape themselves to perfect men,
> That they may know the bounds of Nature's realm,
> (How all things thrive and mix and interweave)
> And last that they may nothing speak except
> What words the wise old masters used to say.
> Those masters urge all mortals who are wise
> To be instructed in the mystic lore
> Of sacred rites, whose meaning they proclaim
> By actions rather than by words of mouth.

His introduction finished, Theophrastos proceeds to give a brief account of the skill of the sophists in the different sciences. He begins most naturally with astrology, for the teachers of that time were firm believers in the power of starry influences.

> We, who foretell just where the stars shall be,
> Who know their natures, heights and intervals,
> Their occultations, when they rise and set,

[1] The Greek text, upon which the translations of Theophrastos and other Byzantine alchemists in this paper are based, is that given in Ideler's "Physici et Medici Græci minores," Berlin, 1841.

Their measured bounds and what their orbs portend,
Do not misread their signs, though far away,
For when assisted by a knowing mind
Our sense of vision sees them as they are.
We know the truth of what is in the sky
Above and are not ignorant of what
Is there performed, for we perceive it all
And make it evident to mortal minds,
As their experience can testify.

Next in importance after astrology Theophrastos places medicine. In the decadence of Greek science, astrology and medicine were always linked together. The Perignostics of Hermes Trismegistos give in great detail the influence of the planets upon the courses of disease.

The most important branch of Byzantine medicine was prognosis, which was elaborated to such a degree that physicians professed to indicate sickness long before the patient felt any of its symptoms. Copious treatises upon diagnosis have come down from Byzantine writers, who describe with great minuteness methods for examining the urine and feces, or for determining the patient's condition from the beatings of his pulse. In the treatment of disease the regulation of diet played a most important part and elaborate regimens were prescribed for the sick for each season and month of the year.

Yet more than this, the causes we reveal
Of each affliction in the body's frame;
Experimentally our school explores
The science, art and ends of medicine,
With such success that our prognosis shows
What sicknesses are destined to appear
And what is best to cure or ward them off;
Its findings also lead us to foretell
An end of life from sickness far from home.

Leaving medicine Theophrastos next briefly relates the investigations of the sophists in the vegetable, mineral and animal kingdoms.

Not only has our wisdom known the ways
By which to check each illness and disease,
—Prodigious wonders even though they be—
But with exactness we describe the flowers,
(Their qualities, their mixtures and their kinds),
And taste of juice and substances of plants.
Each class of growing herbs has been portrayed
For our prognosis and with words exact,
We also know the hues and kinds of stones,
The places where the metals are produced
And all their properties both good and bad.
The many kinds of creatures in the sea
Are known to us and all their many forms;
We teach mankind their natures, good and bad,

How some to use and others to avoid.
Nor do we slight the race of gay-hued birds,
Those strange in form and those who kill their kind,
Those who by nature are of use to man,
And so contribute to the joy of life.
Each class and race of reptiles we describe,
And so all living things find place within
Our catalogue. Nor have we falsified
In anything, for every word is true.
All we have said or shown to mortal men
Is for their use and happiness in life.

But the sophist's career, which Theophrastos has thus far painted in brightest color, was not one of unalloyed happiness. Many of the prose writers among the Greek alchemists dwell upon the opposition which was provoked by their ideas regarding the transmutation of metals, but few of them are as bitter in the denunciation of their critics as the poets. No better example can be found than Theophrastos of that proverbial sensitiveness which Horace states has always characterized the fretful tribe of poets.

How then can those vile critics censure us,
They who in secret learning are inept,
And who in sophic wisdom have no share?
How can they say we sophists speak untruths
With their own minds so pitifully maimed
They give no thought or care to things divine?
They ask how gold is ever to be made,
How that can change which has a nature fixed,
Placed there of old by God the demiurge,
Who formed its substance never to be moved
From that position which from early time
Was its abode and destined resting place;
They say gold thus abides, nor suffers change,
For naught can be transmuted from the class
Or species where its origin took place.
They who speak thus but trifle with their minds
And nothing say that bears the stamp of truth.

The quarrel between the alchemists and their critics involved the old question of the fixity or transmutability of genera and species. It dated back to the time of Aristotle, who was the first to make the distinction between a material cause and a formal cause. The critics of alchemy insisted that matter was unchangeable, that lead always remained lead as gold always remained gold and that the gulf between these two metals was an impassable one.

To the argument for the unchangeableness of matter the alchemists gave complete assent. They replied to their critics:

We agree with you that matter is unchangeable, but you forget that it is not matter which we seek to change but only the form in which this matter is cast. The material substance or stock (φύτη) of lead, gold and

other things is one and unchangeable, and the object of our endeavor is simply to pour the matter from the form of lead into the form which our human perceptions recognize as gold. Just as an artist can take the bronze of an ugly vessel and recast it into a beautiful vase. But if the idea of transmutation seems so irrational, take the case of the sun. He is always the same, yet by his movements along the ecliptic he produces the change of seasons which pass from extreme cold to extreme heat and from extreme moisture to extreme dryness.

The comparison of transmutation with the change of seasons was a favorite one with the Greek alchemists, for it rested upon one of those etymological subtilties which always appealed to the Hellenic mind, the word τρόπη meaning both alteration and season (originally solstice). This play upon words is followed by Theophrastos.

> But we will show the end of this our art,
> An end most useful and most quickly learned,
> For nothing strange it needs save that one stock
> From which all things by Nature are produced.
> From Time's four transformations learn the way
> By which the work most skilfully completes
> The transformations of sophistic art.
> The winter, cold and moist, controls the frost;
> By him the fleeting clouds are borne on high
> To drench the earth and quicken seeds to life;
> Three months elapse before his time expires.
> Next Spring, a season moist and warm comes in;
> By her the earth is made to bloom with flowers
> Of every kind; her course is also run
> When three more months their transformation bring.
> Next Summer, warm and very dry, appears;
> By her Earth's bosom is released from damp
> And, warmed from chilliness, is made to bear;
> Her period in three more months is run.
> The Autumn quickly comes upon his way,
> A season dry and cold in which alas
> The beauty of the flowers is all destroyed;
> His rapid course in three more months is passed.
> Through these four transformations runs the sun;
> He makes his circuit in the dozen months
> Which form the year and sheds his light on all
> Beneath the sky. The splendor of his beams
> Fills all the earth with mild increasing warmth;
> With rapid course he summons things to life
> And makes with gentle heat all trees to bud.
> From him the moon receives her gleaming light
> And all the wandering stars, the planets seven,
> And likewise those whose shining orbs are fixed.

The argument of Theophrastos about the seasons is a brief summary of that given in the fifth praxis of Stephanos, who states that the four elements, earth, water, air, fire, in their cycle of the year form twelve combinations of triads in four

sets. There is thus one triad of elements for each month and a set of three triads of similar elements for each season. The arrangement of this cycle of elements is illustrated by the following diagram.

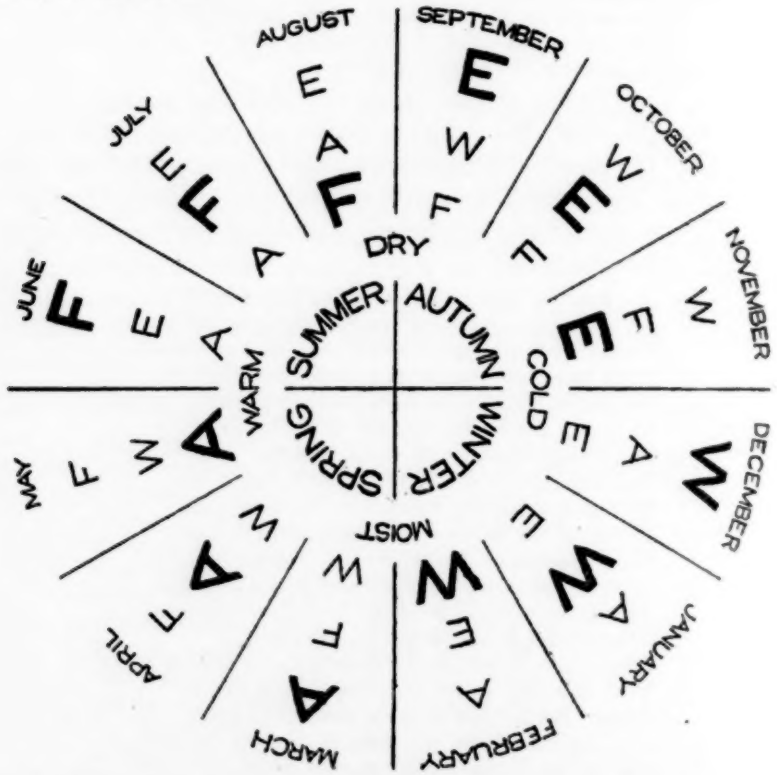

DIAGRAM OF THE YEAR'S CYCLE OF ELEMENTS (constructed from Stephanos).

The Elements Earth, Water, Air, Fire are represented by their initials E, W, A, F; the governing element of each season and month is in large letter. Fire is absent in winter, Earth in spring, Water in summer, Air in autumn. Commencing on the middle circle in Dec. Air goes to the outer circle for Jan., Feb., Mar., crosses in April to the inner circle for May, June, and July and finishes again on the middle circle in August. Then Water follows a similar path, to be succeeded by Earth, the final interweaving circuit of the three rings being completed by Fire.

The quality Moist is common to winter and spring, Warm to spring and summer, Dry to summer and autumn, Cold to autumn and winter.

Theophrastos, in the last line, expresses the belief, common in ancient times, that the fixed stars, as well as the moon and planets, received their light from the sun. As the production of metals, precious stones, etc., within the earth was believed by the ancient alchemists to be due to emanations from the heavenly bodies and, as the light of the moon and planets was received from the sun, the generation of the metals and precious stones could thus be referred to a single influence.

So understand the work, how to refer
The four mutations to one simple form
And from the four to make the work complete,
Seven colored, even as the planets seven,
Whence Nature gets her species, kinds and forms,
Whence Luna's metal takes a whitened hue
And whence proceeds the yellow principle
(That gives a second splendid purple tint)
Which brightening all bodies tinges them
The brilliant golden color of the sun.

Theophrastos having outlined the theory of his art, next takes up its practical execution. His description of the process of gold-making, however, is so obscured by allegory that it is a hopeless task to follow him without referring to the older works.

Transmutation, although described by the Greek alchemists as a conversion of base metals into silver and gold, is everywhere designated as a process of coloring or tingeing. Several methods of tingeing the base metals were employed, but only two of these will be described.

The first method consisted in giving the metal a wash with an amalgam of silver or gold. Upon heating the coated metal the mercury was expelled and a thin film of silver or gold remained. This receipt for silvering, or gilding, metallic objects was an old one. It was a favorite with counterfeiters and was one of the methods resorted to by the Roman Emperors when they wished to debase the coinage. In the practical receipts we find no suggestion of transmutation when this method was used. It is only with the alchemists that the process acquired an additional mystical interpretation. Mercury, which was volatile, was a spiritualizing agent and the leaven, or seed, of precious metal when placed therein had the power of transmuting the baser metal into its own nature. This was illustrated by the sayings.

Just as the yeast of bread can leaven a large mass of dough, so does a little silver or gold act. He who sows wheat produces wheat and harvests it, in the same way gold produces gold and silver produces silver.

In the first method of tingeing metals the coloration took place only upon the surface. In the second, and to the alchemists the most important, method of tingeing the change in color was effected throughout the whole body of metal. The earliest writers drew a clear distinction between these two methods, the Pseudo-Democritos being among the first to condemn those who supposed that mercury should act only upon the surface. The means by which the Greek alchemists claimed to transmute the entire body of base metal into gold can only be understood by going back to the oldest receipts.

When the Greeks under Ptolemy took possession of Egypt they found in the temples a vast collection of practical receipts which were jealously guarded by the Egyptian priests. These ancient books, which formed a large collection of works upon pharmacy, metallurgy and other arts, were ascribed by the Egyptians to Thoth whom the Greeks identified with their god Hermes. These books have all been lost with the exception of one manuscript upon medicine, the so-called Ebers papyrus written about 1500 B.C., which contains various pharmaceutical and magical prescriptions for treating diseases. The mention in this manuscript of such substances as copper, lead, iron, stibium, asem (a gold-silver alloy), sulphur and soda and the reference to such operations as roasting, cooking, melting, extracting and filtering shows that the early Egyptians were familiar with the products and processes of practical chemistry. It is unfortunte that none of the Hermetic books upon metallurgy have survived. Allusions to these books by Olympiodoros and other Greek writers show, however, that the Egyptian priests possessed a vast amount of information upon the smelting, alloying and coloring of metals. Translations of some of these Hermetic receipts have no doubt been incorporated into the collections of the Greek alchemists.

Although the ability to transform the base metals into silver and gold was attributed to the Egyptians by the Greek alchemists, we find no historical mention of this until about 290 A.D. when the Roman Emperor Diocletian destroyed the books of the Egyptians upon the chemistry of gold and silver. The incident is thus commented upon by the historian Gibbon:

> At the same time that Diocletian chastised the past crimes of the Egyptians, he provided for their future safety and happiness by many wise regulations, which were confirmed and enforced under the succeeding reigns. One very remarkable edict which he published, instead of being condemned as the effect of jealous tyranny, deserves to be applauded as an act of prudence and humanity. He caused a diligent inquiry to be made "for all the ancient books which treated of the admirable art of making gold and silver, and without pity committed them to the flames; apprehensive, as we are assured, lest the opulence of the Egyptians should inspire them with confidence to rebel against the empire." But if Diocletian had been convinced of the reality of that valuable art, far from extinguishing the memory, he would have converted the operation of it to the benefit of the public revenue. It is much more likely that his good sense discovered to him the folly of such magnificent pretensions, and that he was desirous of preserving the reason and fortunes of his subjects from the mischievous pursuit. It may be remarked that these ancient books, so liberally ascribed to Pythagoras, to Solomon, or to Hermes, were the pious frauds of more recent adepts. The Greeks were inattentive either to the use or to the abuse of chemistry. In that immense register, where Pliny has deposited the discoveries, the arts, and the errors of mankind,

there is not the least mention of the transmutation of metals; and the persecution of Diocletian is the first authentic event in the history of alchemy.

The question "if the Egyptians could make gold why did Diocletian not avail himself of the knowledge?" has puzzled many a writer. We know that the financial condition of the Roman Empire at this time was a desperate one. The argenteus, of which sixty were originally coined from a pound of silver, had, under succeeding Emperors, been continually debased. In the reign of Gallienus the argenteus consisted only of base metal plated with silver. The final limit was reached when it was made of copper and counterfeited to resemble silver by a wash of tin.

Diocletian adopted heroic remedies to relieve the financial condition of his empire by regulation of taxes, fixation of prices and restoration of the silver coinage. From the information contained in papyri, that have recently been published, we now know that Diocletian's destruction of the chemical treatises of the Egyptians was directly in line with these reforms. Counterfeiting had reached a higher state of perfection in Egypt than in any other part of the Roman Empire and when the practical-minded Emperor discovered that the chemical books of the Egyptians gave detailed information for imitating silver and gold he very properly burned these treatises as one of the causes of the Empire's financial troubles. Stringent measures were taken to enforce these regulations and the counterfeiters, who previously worked in the open, were now compelled to labor in secret. Their practical knowledge of the art was rewritten in an obscure enigmatic language which if discovered would deceive the military inspectors. This obscurity was still further enhanced by the decline of the metallurgic arts and the influence of Greek, Jewish and Gnostic mysticism, until what in the older days was bluntly admitted by the practicians to be a fraud was now acclaimed by the speculative mystics to be a transmutation.

This view of the origin of alchemy which was advanced by Berthelot[1] has been amply confirmed by the publication in re-

[1] "It was thus that the workmen, accustomed to compound alloys resembling gold and silver with such perfection that at times they deceived even themselves, ended by believing in the possibility of an actual creation of these metals." (Berthelot, Alchemistes Grecs, Introd., p. 73.) The Upsala papyrus was not published until 1913 (Papyrus Græcus Holmiensis, Upsala A. B. Akademiska Bokhandeln). Could Berthelot, who saw the great importance of the Leyden papyrus, have only lived to read the Upsala papyrus, he would have seen the most complete verification of his views. Lagercrantz, in his scholarly edition of the Upsala papyrus, discusses the whole question exhaustively and adopts the same view of the

cent years of two Greek papyri belonging to libraries in Leyden and Upsala. These papyri, which have been described as twin-brothers, were discovered in Egypt nearly a century ago by natives, while engaged in the plunder of tombs, but it is only lately that their contents have been made known. The two documents consist of over 250 receipts for purifying and treating metals, for preparing alloys, for counterfeiting gold and silver, for imitating pearls, emeralds, sapphires and other precious stones and for preparing colors and dyes. Only a few of the receipts for counterfeiting gold and silver will be quoted.

To adulterate gold (χρυσοῦ δόλος). An equal part of misy and Sinopic rouge to an equal part of gold. Put the gold in a furnace and when it is bright add each of the other ingredients. Take out and let cool when the quantity of gold is doubled. (Leyden papyrus, Rec. 17.)

To make silver (ἀργύρου ποίησις). Clean white soft tin four times, melt six parts of the same with one mina of white Galatian copper. It becomes prime silver that will deceive even skilled workmen who will not suppose it to be made by such a treatment. (Upsala papyrus, Rec. 3.)

Another receipt. Add six parts of purified tin and seven parts of Galatian copper to four parts of silver and the resulting product will pass unnoticed for silver bullion. (Upsala papyrus, Rec. 4.)

The receipts just quoted are all manifestly fraudulent as they are stated to be in the directions. One other receipt for making silver has an interesting significance, as it makes use of mercury, the spiritualizing medium of the later alchemists.

To make silver. Purchase coals such as the coppersmiths use and steep them in vinegar for one day. Then take one ounce of copper, fix it well with alum and melt in this condition. Then take eight ounces of mercury and empty the same into poppy extract. Take also one ounce of silver and, having incorporated these ingredients together, melt. (Upsala papyrus, Rec. 8.)

The Leyden and Upsala papyri were written apparently towards the close of the third century and are to be regarded as prototypes of the later alchemical receipts, the earliest manuscript of which dates back to the eleventh century. The connection of the two classes of documents with one another is unmistakable. The papyri refer to Democritos and Aphrikanos, who are mentioned repeatedly by the alchemists. Many

fraudulent origins of alchemy. "The Egyptian priests are therefore to be regarded as the oldest representatives of the art of adulterating gold, silver, precious stones and purple. Since the preservation of receipt books in the temples is expressly mentioned, then in all probability we should regard these places also as workshops for counterfeiting. If any one should think such a calling not to conform exactly with the virtues of priesthood, we would reply by saying that we should not entertain too exaggerated ideas of the morality of this profession. Moreover an outward show of uprightness could easily be given to operations from which the public at large was naturally excluded."

of the receipts in the two collections are identical and the occurrence of the term an inexhaustible cake (*ἀνέκλειπτος μᾶζα*) of metal in both the papyri and the alchemists shows a certain community of origin.

The two papyri no doubt belong to the class of chemical books which Diocletian destroyed, the accident of burial, or concealment, having secured their preservation. They offer a good illustration of the practical receipts of the Egyptians before they were obscured by the allegorical interpretations of later mystics.

Under Christian influences this allegorizing tendency was further accentuated. The technical term for coloring is *βάπτειν*, to dip, and the close resemblance of this word to its cognate, *βαπτίζειν*, to baptize, conveyed a spirit meaning of the process to the Christian alchemists of the Byzantine era. Allusions to the New Testament became frequent. Chemical processes are represented under such terms as baptism, bodily death and resurrection, while the whole language is permeated with mystical expressions. Each metal, the same as man, becomes endowed with the triple hypostacy of body, soul and spirit. "The aim of our philosophy," writes Stephanos, "is the separation of soul and body." Divest lead or copper of its soul and spirit, endow the resulting body with a soul and spirit of a higher type and the result is gold. The change from the black of lead or the red of copper to the yellow of gold could not, however, be accomplished directly. The base metal must first be brought to the whiteness of silver before projection of the stone can produce gold. This is indicated in the lines of Theophrastos:

> The white, augmented thrice within a fire,
> In three day's time is altogether changed
> To lasting yellow and this yellow then
> Will give its hue to every whitened form.
> This power to tinge and shape produces gold
> And thus a wondrous marvel is revealed.

The great agent of transmutation was the stone. "It is found," said Avicenna, "in the dirt of streets and is trodden under foot by men." The Greek alchemists were no less explicit. "It can not be bought with gold," said an unknown prose writer, "yet God has given it freely to beggars." Zosimos, a Greek of Panopolis, described it as "a stone yet not a stone, a thing despised yet full of honor, of many forms yet shapeless, a thing unknown yet familiar to all, of many names yet nameless." The description of Theophrastos is equally obscure.

Though not a stone, it yet is made a stone
From metal, having three hypostases,
For which the stone is prized and widely known;
Yet all the ignorant search everywhere
As though the prize were not close by at hand.
Deprived of honor yet the stone is found
To have within a sacred mystery,
A treasure hidden and yet free to all.

The symbol of chemical change from the earliest days of alchemy has been the fiery dragon or salamander. In the form of a dragon devouring its tail and bearing the mystical motto of three words and seven letters, ἕν τό πάν, "The All is One," it was used by the Greek alchemists to typify the unity of matter. It was the symbol of the never-ending cycle of the elements; the appearance of matter is always changing, yet its substance is eternally one and the same.

The first step in the process of transmutation, the process of albifaction (λεύκωσις) or conversion of the base metal into silver, is thus described by Theophrastos under the symbol of the dragon.

A dragon springs therefrom which, when exposed
In horse's excrement for twenty days,
Devours his tail till naught thereof remains.
This dragon, whom they Ouroboros call,
Is white in looks and spotted in his skin,
And has a form and shape most strange to see.
When he was born he sprang from out the warm
And humid substance of united things.
The close embrace of male and female kind,
—A union which occurred within the sea—
Brought forth this dragon, as already said;
A monster scorching all the earth with fire,
With all his might and panoply displayed,
He swims and comes unto a place within
The currents of the Nile; his gleaming skin
And all the bands which girdle him around
Are bright as gold and shine with points of light,
This dragon seize and slay with skillful art
Within the sea, and wield with speed thy knife
With double edges hot and moist, and then,
His carcass having cleft in twain, lift out
The gall and bear away its blackened form,
All heavy with the weight of earthy bile;
Great clouds of steaming mist ascend therefrom
And these become on rising dense enough
To bear away the dragon from the sea
And lift him upward to a station warm,
The moisture of the air his lightened shape
And form sustaining; be most careful then
All burning of his substance to avoid
And change its nature to a stream divine

With quenching draughts; then pour the mercury
Into a gaping urn and when its stream
Of sacred fluid stops to flow, then wash
Away with care the blackened dross of earth.
Thus having brightened what the darkness hid
Within the dragon's entrails thou wilt bring
A mystery unspeakable to light;
For it will shine exceeding bright and clear,
And, being tinged a perfect white throughout,
Will be revealed with wondrous brilliancy,
Its blackness having all been changed to white;
For when the cloud-sent water flows thereon
It cleanses every dark and earthy stain.
Thus he doth easily release himself
By drinking nectar, though completely dead;
He poureth out to mortals all his wealth
And by his help the Earth-born are sustained
Abundantly in life, when they have found
The wondrous mystery, which, being fixed
Will turn to silver, dazzling bright in kind,
A metal having naught of earthy taint,
So brilliant, clear and wonderfully white.

With the help of the practical receipts and early prose treatises upon alchemy we are able to form some idea of the operations thus described.

It was recognized by the very earliest writers upon alchemy that the two important conditions necessary for promoting material change were heat and liquidity. Solution of the interacting substances was first necessary and to effect this solution heat and a liquid solvent were required. "Corpora non agunt nisi soluta" was a tenet of the medieval alchemists, an expression which was simply borrowed from the *ἀναλνόμενα πάντα ἐργάζεται* of the Greeks. When Theophrastos states, therefore, that the dragon is born from "warm and humid substance" and is to be slain in turn by a "knife with double edges hot and moist," we are simply to infer that the ingredients of his preparation are to be acted upon by some liquid through the agency of heat. The ingredients in this case, as in receipt No. 8 of the Upsala papyrus, are copper and silver and the acting liquid, as in the same receipt, is mercury.

Theophrastos describes his ingredients as male and female, a method of appellation common to the alchemists, who classified nearly all their substances under the one or the other of these terms. One very important male ingredient, used for the white coloration of copper, was arsenic, the word *ἀρσενικόν* in Greek meaning either arsenic or masculine. The connection of gender, however, is not always so apparent as this. Another means of differentiation was based upon the gender of

the word, planet or deity representing the substance. Thus lead and gold are always masculine whether represented under the common names μόλυβδος and χρυσός or under the planetary names Κρόνος and Ἥλιος. Copper and silver, on the other hand, are masculine under the common names χαλκός and ἄργυρος, feminine under the planetary names Ἀφροδίτη and Σελήνη. Copper, however, is stated by nearly all the alchemists to be a man, while silver is constantly referred to as copper's bride, the union of the two being symbolized as a marriage.

The mystical marriage of copper to silver was not accomplished, however, by melting. The fusing together of copper and silver into the alloy was recognized by the alchemists as a blending (κρᾶσις) and not as a uniting (ἕνωσις). For the actual union of two opposites Greek philosophic ideas required the action of an intermediary which shared the qualities of the two elements or substances. The old alchemists dwell constantly upon the necessity of this. Fire, for example, is warm and dry, while water is moist and cold. These two opposites are joined by the intermediary action of air which is warm and moist.

The intermediary agent employed in the union of copper to silver was mercury, which in some of its attributes shared the qualities of both these metals. For example, mercury in color resembled silver, while its oxide in color resembled copper. But the point upon which the alchemists placed most stress was the intermediary influence of gender, mercury being both male and female. In the Upsala papyrus we find the masculine form ὁ ὑδράργυρος in the eighth receipt and the feminine form ἡ ὑδράργυρος in the seventeenth. The same difference in gender is also observed in other technical treatises. The classic Greek writers used the masculine form, but most of the alchemists employed the feminine, although recognizing the distinction of double gender. Zosimos, for example, in one of his allusions to mercury says "it is the silvery water, the masculine-feminine (τὸ ἀρσενόθηλυ), that which is always running away and yet hastening unto its own."

The union of copper and silver is referred to by Theophrastos as taking place within the sea, the latter being a common term for the liquid metal mercury. The amalgamation is hastened by warming the vessel containing the ingredients in fermenting horse dung for twenty days. At the end of this time all traces of metal have been dissolved by the mercury, or as Theophrastos says the dragon "devours his tail till naught thereof remains."

The mixed amalgam of copper and silver, which according to Theophrastos was a speckled white, was next transferred to some form of Egyptian alembic, such as were made at Alexandria, an operation alluded to by saying that the dragon "comes unto a place within the currents of the Nile." The mixture is then heated over a gentle fire until the mercury is distilled away, this part of the operation being indicated by such terms as slaying the dragon "with skillful art within the sea," "Clouds of steaming mist ascend therefrom and these become on rising dense enough to bear away the dragon from the sea," etc. The vapors are condensed in the head of the alembic, "its nature changed into a stream divine," after which the liquid mercury is poured out into a recipient. Theophrastos here for the first time banishes allegory and calls mercury by its actual name, the sign of the waxing crescent being affixed to remove all doubt of his meaning.

During the distillation of the mercury a dross of black oxide gathered on the surface of the melted contents of the alembic, a phenomenon alluded to as the lifting out of the gall, and the removal of "its blackened form all heavy with the weight of earthy bile." The final flashing of the melted metal under the scum of oxide, which Theophrastos mentions under such terms as brightening "what the darkness hid within the dragon's entrails," is, according to Hoefer, exactly what the metallurgist to-day observes in the cupellation of silver.

The mass of metal in the alembic is then cooled and scrubbed with running water which "cleanses every dark and earthy stain." The silver-copper alloy thus obtained is described by Theophrastos as "silver dazzling bright in kind, a metal having naught of earthy taint."

The transmutation of copper to silver by the above process is described by many of the Greek alchemists as a combat or battle in which the male contestant copper is completely vanquished by the female victor silver.

Stephanos in his fourth praxis exclaims:

> Fight copper! Fight silver! Join male and female! The copper in his contest with silver is destroyed; the silver by her combination with copper is fixed. Destroy the body of copper and make it incorporeal by means of silver.

So also Archelaos in his poem causes the soul of copper to address its lifeless body:

> Thou dost not wait the female joined to thee
> In wedlock as desired. Thou dost not check
> The clash of female conflict but decay
> Awaits thy bloom from her.

It is seen from this that Mr. Kipling was not the first poet to declare, "The female of the species is more deadly than the male."

The first step of transmutation, the albifaction or λεύκωσις having been accomplished, there only remains the final step, the yellowing or ξάνθωσις, by means of which the silver is transformed to gold. This part of the process is described by Theophrastos as the second slaying of the dragon.

> Then seize again this dragon changed to white
> (A change divinely wrought, as I have said,
> By means of albifaction twice performed)
> And slaying him again with knife of fire
> Draw all his blood which gushes blazing hot
> And red as shining flame when it ignites.
> Then dip the dragon's skin into the blood
> Which issued from his belly's gory wound
> (As thou wouldst dip a whitened robe in dye
> Of murex purple); so wilt thou obtain
> A brilliant glory, shining as the sun,
> Of goodly form and gladdening the heart
> Of mortals who behold its excellence.

This second slaying of the dragon is accomplished by heat alone, the agency of liquid mercury not being required. The weapon this time is "a hot knife of fire" in place of the "knife with double edges hot and moist" previously employed. The metal from the first transmutation is accordingly re-melted over a hot fire preparatory to the addition of the stone, or powder of projection, by means of which the conversion of the silver to gold is to be accomplished. This is done by drawing off the melted metal, which Theophrastos calls the blood of the dragon, and stirring into it the powder of projection, an operation which is poetically described as dipping "the dragon's skin into the blood."

The composition of this "dragon's skin," or stone, or powder of projection, was the chief subject of investigation by the medieval alchemists, who wrote countless treatises upon the subject. Without discussing any of the medieval receipts it may be said that reference to the oldest writings indicates that the so-called stone was originally a yellow powder composed of such ingredients as copper, cuprous oxide, cinnabar, litharge, yellow arsenic or orpiment, misy (a copper-containing pyrites), sory (basic sulphate of iron), sulphur, and other substances whose yellow color might be a recommendation. A certain amount of gold was also probably included to act as a seed or leaven.

In a receipt, previously quoted from the Leyden papyrus for adulterating gold, misy and Sinopic rouge are mentioned as

ingredients to be added to the gold and we have here probably a germ of the later powders of projection.

A somewhat fuller receipt is given in the Pseudo-Democritos:

> Lighten the color of cinnabar by means of oil, vinegar, honey, brine or alum; then make it yellow by means of misy, sory, flower of copper, nature sulphur, or in any way desired. Project this upon silver and it will be gold.

A considerable latitude is given in these directions, as is indicated by the expression, "or in any way desired." The rigid exactness of the medieval alchemists, who permitted not the slightest deviation in character or quantity of the ingredients, is not as yet apparent.

Two very important substances, used by the Greek alchemists in projections, were the so-called molybdochalc (*μολυβδόχαλκος*) and aphroselen (*ἀφροσέληνον*). Owing to the very inexact nomenclature of the times, these words were given to a variety of products, although the terms seem most generally applied to the oxidation products obtained in refining lead-copper and copper-silver ores. The waste dust of the lead, copper and silver smelting works was especially prized by the old alchemists. This dust, described under such names as cadmia, tutia, magnesia, tephra, pompholyx, little scoriæ, etc., fulfilled the mystical requirements of the stone, "being a product of many names, of no value, found in the dust of streets and trodden under foot by men." The incorporation of metallic oxides into the tinctorial powder or stone is alluded to by Theophrastos where he says "though not a stone, it yet is made a stone from metal."

The substances entering into the tinctorial powder were obtained in many cases by subjecting the metals themselves to a process of corrosion (*ἴωσις*). The directions for preparing molybdochalc according to a receipt of the Pseudo-Democritos were to heat white lead, or litharge, with flower of copper, or roasted copper, or treated copper-rust until the mixture became yellow. The manufacture of some of these ingredients, according to accounts given in Dioscorides and Pliny, will be briefly described.

White Lead (Greek, *ψιμύθιον*; Latin, cerussa) was made as follows: plates of lead were put into jars containing vinegar and kept closed for ten days. The corrosion that formed upon the surface of the metal was then scraped off and the lead put into the vinegar again. The process of corroding and scraping was continued until the whole of the lead was consumed. The scrapings were powdered, sifted, and dried in the sun. The method thus described is about the same as the modern

Dutch process for making white lead. The white lead obtained was used as such, or else was heated in shallow pans until it was converted into the yellow or red oxides. These changes of color from the black of lead to the white of the basic carbonate and to the yellow of the oxides were of especial significance to the alchemists, for they followed the traditional order which base metals should follow in their conversion to silver and gold.

Flower of Copper (Greek, χαλκοῦ ἄνθος; Latin, æris flos) was made in several ways. In one method the fused metal was exposed to a blast of air which caused the surface to peel off in small scales. In another method the scales were formed by drenching the hot metal with water. The scales, after being powdered, had a reddish-yellow color and consisted of a mixture of metallic copper and cuprous oxide.

Roasted copper (Greek, χαλκὸς κεκαυμένος; Latin, æs ustum) was made by heating copper in closed vessels with various substances, such as sulphur, salt, alum, and vinegar. The calcined residue was then powdered in a mortar, washed and sifted. It consisted of a reddish-yellow powder and had a composition resembling that of flower of copper.

Copper rust (Greek, ἰός; Latin, ærugo) or verdigris was made by sprinkling vinegar upon copper filings or by putting plates of copper into earthern pots containing vinegar and scraping them every ten days. The scraped rust referred to in the receipt of Pseudo-Democritos was not used directly in making the powder of projection, but was treated, a process which, from a description of Dioscorides, probably consisted in heating the verdigris in a closed vessel until the basic acetate was changed into a red suboxide of copper.

The scraping of the corrosion or oxide from the metal plates, mentioned in these processes, is the operation described by Theophrastos and other alchemists as "skimming the dragon," the figurative skin, which was removed, forming the basis of the older powders of projection.

The action of the "dragon's skin," or stone or powder of projection, upon the silver-copper alloy of the first treatment would simply be to increase the copper content of this alloy and give it a golden color. The seed of gold and unchanged copper in the preparation would of course be readily taken up. The suboxide of copper has also a certain solubility in melted alloys of this kind and would help to impart a red or yellowish tint to the resultant mass of metal. Any unabsorbed ingredients, such as sulphur, orpiment, cinnabar, litharge, etc., would be either colatilized or thrown out as dross. The fused alloy after drawing off and casting probably had a yellow color

much like that of gold. It might possibly "escape detection by skillmen workmen," to use the unsophisticated language of the old receipts, and to the credulous-minded alchemists, who had forgotten the old Archimedean method for determining the purity of metals, might easily pass for gold so pure that even "the treasuries of kings did not possess the like."

A final question, which remains to be considered, is the quantity of tinctorial powder that was used for projection. In the Leyden papyrus the receipt for adulterating gold prescribed "an equal part of misy and Sinopic rouge," and we can infer from other practical receipts that the amount of material used in the early days for tingeing metals the color of gold was considerable. In one Greek manuscript the directions state: "As to the weight of the projection, in the first operation one weight is projected into one weight; in the second one weight into a thousand weights; in the third one weight into a million weights." We know from the old writings that the process of projection was frequently repeated and with each repetition of the process the quantity of powder was diminished.

When the old practical receipts became permeated with mysticism, the idea of a seed or leaven, which could transform an almost unlimited amount of base metal, got the upper hand. The quantity of powder was reduced until in the middle ages it was held that one grain of powder could transmute whole oceans of base metal into gold. By thus diminishing the quantity of powder the coloration produced by the older methods of projection was no longer obtained and the composition of the powder was held to be lost.

The subject of alchemy offered the Byzantine schoolmen a convenient theme for the exercise of rhetorical flourishes and Theophrastos next proceeds in a kind of litany to tell how the fortunate ones, who have been enriched by alchemy, express their appreciation.

They praise the gift with wise and joyous words
As one divinely sent and great in worth;
And thus they speak and voice their thankfulness.
O work divine, well-pleasing and concise!
O beauty brilliant with an aspect clear!
O marriage and conjunction most renowned!
O husband in a single union joined!
O wife united by affection deep!
O offspring famous and with glory filled!
O progeny of splendor, light and worth!
O robe with gold and silver overlaid!
O double-folded mantle bright as snow!
O metal which with gleaming silver teems!
O clear refreshing river of the sea!

O water than the loosened earth more free!
O ether rising far above the earth!
O clouds transformed from blackness into white!
O brilliant colored glory of the heaven!
O light which shines to all beneath the sky!
O system and bright circuit of the stars!
O lunar light reflected from the sun!
O sun whose darting beams engender gold!
From these the work of every sage begins
To reap in practise some deserving end;
In thee appears the object of our search;
Thou shinest scattering thy wondrous light,
A treasure most desired, all filled with pearls;
And bringing gain and wealth to mortal men.

This rhapsody, which repeats in gorgeous rhetoric the various steps of transmutation, seems somewhat overdrawn, yet Theophrastos in the use of exclamation is mild when compared with Stephanos, who in page after page of his prose treatise upon the sacred art lets flow a muddy stream of bombastic Greek. The science of the early Alexandrians had so far degenerated in the days of the Byzantines that it was made a theme for rhetoricians while the ancient clarity and conciseness, which made the scientific writings of Hippocrates and Archimedes models of expression, had now given way to deliberate obscurity of thought and to the empty jingling of an inflated style.

The alchemical poets conclude their verses with reflections of a moral and religious nature. This also was in general keeping with the custom of Stephanos and other Byzantine writers whose treatises usually began and ended with a prayer. Theophrastos simply followed the usage of his time and concluded his poem as follows:

Who, then, beholding the great universe
Which Thou hast wisely wrought,—a well-designed
Production, made with singleness of art,
And faith inspiring in its glorious works—
Entranced with wonder would not be amazed?
He would extoll the boundless providence
Of reason's God and praise the sympathy
Which He, in ways both wise and manifold,
To us declares. As Lord beneficent
He wishes all mankind a happy life
And wealth by their activities to gain.
Then let us shape life's course with reverence
And cherish piety's clear beacon light,
Our pathways brightening with godly deeds,
Our neighbor loving and the foreign guest;
And day and night with supplicating prayers
Our adoration pay, as servants wise,
To God the Lord, all-seeing King of all,

Forgiveness asking for our trespasses
And that all kin from danger may be spared
And from temptations freed, as they arise;
And let us never undertake a work
Unless we give the praise therefor to God,
The Father, who begot the only Son,
The Son, the holy Word from God produced,
The Holy Ghost, proceeding too from Him,
Both now and always evermore. Amen.

This ending in orthodox Greek fashion is typical and reflects in a measure the ecclesiastical mania of the times, which found its expression in liturgies, ceremonies and the other accompaniments of an extravagant ritual. The doctrine of the Procession of the Holy Ghost from the first person of the Trinity, contained in the next to the last line, shows that the poem was composed after the Council of Chalkedon in 451, and so could not have been written before this date as some have supposed. The same doctrine is promulgated in Stephanos to the disgust of Reinesius who, however much he admired the opinions of this writer on the subject of transmutation, could not uphold him in this.

The moral admonitions contained in Theophrastos and the other Greek alchemists were not, however, entirely the result of ecclesiastical influences. As the mystical doctrines of the alchemists gained ground the transmutation of the base metals into gold began to be regarded as a symbol of the transformation of man's own lower nature into something nobler and higher. The comparison of the nature of man with that of the metals was used, in fact, by Greek writers of the earlier Alexandrian period. Plotinos writes: "As gold is contaminated by the adherence of earthy dross, so is the soul corrupted by its union with the body." Hierocles makes a similar comparison in his commentary upon the Golden Verses of Pythagoras, where he says, "Gold is symbolic of virtue because it never corrodes while the baser metals gather rust which is typical of the vice that arises from material contaminations."

An example of the extension of this comparison, after the belief in transmutation had gained currency, is found in a fragment of so-called political verse, attributed to John of Damascus, who lived between 700 and 754. The poem, in which the lines occur, was called the Dioptra and gives a dialogue between the soul and body. The body mentions the unapproachableness of the state of man to that of God, but the soul in reply expresses the possibility of transforming man's condition by the following comparison:

It is as if when lead and gold are banished far asunder
A distance from each other's home, a distance wide are parted,
A certain craftsman then should come, who wished to show his cunning,
The operation of his art and scientific knowledge,
Should take this lead and melting it within his blazing furnace
Should show the same transformed to gold of quality the finest.
And this is surely wonderful and strange beyond believing
That what was never gold before, now gold becomes at present,
What was not gold has gold become, though not so at commencing.
O great display of excellence! O great display of reason!

The alchemists, who were always immoderate in their use of symbols, finally carried this comparison to its ultimate extreme with the result that the symbol became of paramount importance, while the act of material transmutation sank into insignificance. Stephanos, the chief Byzantine writer upon the sacred art, makes the following digression towards the close of his eighth praxis:—

From the objects of sense perception pass over now to those sights which are perceived by the mind. Behold the great order and immaterial splendor of the heavenly bodies. When thou hast seen the beauty of these, lift up thy mind beyond and noting the resplendent glory and great joy of the angels do not hereafter be led astray with respect to the material transformation of this earthy substance, of that which is sought after by the hand and revealed by the philosophy of gold-making.

It is not surprising, therefore, that certain writers upon the subject should hold that all the old treatises upon alchemy are simply moral and religious allegories and that the gold, "such as was not found in the treasuries of kings," was of a heavenly, and not of an earthy, kind. An American writer, Ethan A. Hitchcock, was the first to advance this view in 1857 in an anonymous book of some three hundred pages. The same opinion in a modified form is also held by the well-known English writer, A. E. Waite, best known for his scholarly edition of Paracelsus.

The theory, however, that ancient alchemy was a moral allegory and nothing more carries with it its own refutation, for if we accept it as true we must also admit that there was a strong contemporary belief in the actuality of transmutation, otherwise the symbol and allegory would have had no meaning.

It was a strange reversal of ideas that the so-called sacred art, which originated in the fraudulent practises of Egyptian counterfeiters, should have afterwards developed into a means for the inculcation of virtue and religion.

THE ECONOMIC PROBLEM OF THE OZARK HIGHLAND

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THE term Ozark associates a group of regions possessed of widely divergent characteristics. Simplicity and similarity are hardly more representative of the Ozark areas than they are of the regions grouped together under the term Appalachian. In the Missouri Ozarks eight distinct divisions must be recognized, and for Arkansas at least two more are to be added. It becomes a matter of more than ordinary difficulty therefore to speak of conditions and problems in the Ozark Highland as a whole. Yet there must be an adequate geographic unity, otherwise popular usage, unbiased in this case by common political traditions, would not have set up this regional designation.[1]

(1) The Ozark areas constitute a compact highland, for the most part notably elevated above the adjacent areas. This is the common factor in the topography and for this reason no more precise term than highland can be employed appropriately in a geographic sense. In the interior the highland consists of a remnant plateau area, broken into long shreds by stream dissection. Except on the west, hill belts, of very difficult character, surround the central region. The outer flanks of the hill regions, with the exception of the southern and southeastern portions of the highland, are adjoined by less rough border areas of superior resources and development. (2) Even in the Ozark areas of least relief there is more rough land than in adjacent regions which usage does not place in the highland. (3) Ridges and valleys are sharply differentiated. The topography is dominantly of the ridge-and-valley type. (4) Most of the area has been sculptured out of limestone by streams with the abundant aid of underground solution. A close genetic relationship exists between the widely distributed sinks, caverns, springs, and the lead ore, iron ore, and other mineral

[1] The differentiating characteristics of the several parts of the highland and their economic effects are considered in detail in the volume by the author, "The Geography of the Ozark Highland of Missouri," published as Bulletin 7 of the Geographic Society of Chicago (1920).

deposits. (5) A significant property of the Ozarks is the almost universal distribution of chert fragments over the surface. These produce similar effects on slopes, soils, stream beds, and on agricultural practises and roadmaking. Such in the main are the common qualities that are opposed to the multitude of differentiating conditions.

In the following pages the attempt is made to determine whether there exists also a common economic problem for the area as a whole. The inquiry is concerned chiefly with the heart of the Ozarks, namely, with the central plateau and its surrounding hill areas. Just as popular usage is uncertain regarding the inclusion of the border areas in the highland, so the economic conditions of the borders are only in limited degree typical of the area as a whole and the generalizations that follow can be applied to such regions as the Springfield, Missouri River, and Mississippi River borders only with important reservations and exceptions.

The most common conception current regarding the economic character of the Ozark region is its inferiority to the regions that lie about it. The idea is substantially correct and may be demonstrated statistically in many ways by the values and amounts of crops and of other products which the area yields.[2] These facts appear to register the adjustment of a group to an inferior environment. This is true in part, but it does not fully account for the economic situation. There still remains to be considered the question whether the Ozarks are underdeveloped relative to such resources as are available under present economic conditions. In particular it is necessary to inquire whether the economic adjustment is to the present or to a previous value of the environment, for the environment is not necessarily a static factor uninfluenced by the passage of time and the changes in opportunities of production. The case to be examined concerns the possibility of an original adjustment which has since been revised insufficiently, with the result that the Ozark Highland has fallen behind seriously in the progress that may be expected of it, making all due allowances for thin soils, steep slopes and other handicaps.

When settlement west of the Mississippi River began, the flanks of the Ozarks were preferred to all other territory in upper Louisiana. This preference continued beyond the time when Missouri and Arkansas were admitted to statehood, and

[2] For illustrations see volume *op. cit.*

was based on the variety and balance of the local resources rather than on the large amount of any one resource. It was the possibility of sufficiency and especially of self-sufficiency that caused to be located in this area the first American settlements west of the Mississippi. When transportation facilities made commercial production possible in the West, farm immigration was diverted to other areas. The true pioneersman, however, not intent on producing a surplus of crops for sale, was able to occupy step by step the whole of the Ozarks, conscious of no deterioration of his environment as he penetrated into areas of longer and steeper hills. For was there not everywhere good hunting and fishing, excellent water, grazing for his horses and cattle, mast for the hogs, and patches of bottom land for corn, beans and pumpkins? Here he could meet his own needs of lead and gunpowder, dig his iron ore and smelt it, and have ample power for his grist and carding mills. Frontiersmen, rather than agriculturists, became the permanent occupants of the area. With the filling up of adjacent regions, the Ozarks became a sort of refuge to the men who clung to frontier life. After a fashion the frontier still lingers in the Ozarks, but the unconstructive character of frontier living and the increase of population have gradually caused the disappearance of some of the more agreeable features of this life. For an understanding of the area it is essential to keep in mind its antecedents, and also that the blood of the frontiersman is still dominant among the population.

At present, the Ozarks contain somewhat less than thirty per cent. of the population of Missouri, resident on approximately half the area of the state. Since a full third of the people of Missouri live in St. Louis and Kansas City, the population of the Ozarks is nearly of the same density as in the rest of rural Missouri. The situation in Arkansas is similar. Whereas immigrants have not been numerous, serious loss by emigration began later than in other near-by rural districts. Population had not increased to the limit for the food supply under the methods of production practised, and the world outside was little known. The last census, in 1910, was the first to record declining numbers over widespread areas. In the beginning of the new century, rural free delivery of mail became generally established and a serious blow was dealt thereby to the old isolation that had kept people at home. The effects of the late war probably will be even more far-reaching. In 1917 the government placarded the most remote

post-offices with calls for workers in war industries and offered the opportunity of rendering a service to the nation and of securing wages of a magnitude unheard of in this country where wages for the most part have been nominal. Large numbers left for the cities of Illinois and northern Missouri and for the mining and oil fields. The draft took thousands of young men away from home for the first time, and introduced them to new standards and modes of life. Many are not returning. The great prosperity that is continuing through the country has found only a weak echo in the hills of the Ozarks and additional workers are still leaving to share in the high wages outside. The past five years, therefore, have seen a critical increase in the emigration. The old contentment with the simple home in the hills was based in part on a lack of knowledge of outside conditions. A world catastrophe has supplied this knowledge. The selective elimination of the more ambitious of the younger generation is in full progress.

Under these circumstances attempts by railroad immigration officials and state bureaus to direct immigrants into the Ozarks are misplaced. If any effort is worth while it must be concerned with retaining the native population. Relative to developed resources the highland is more densely settled than its neighboring areas, and largely in consequence labor commands lower returns. Emigration is natural and inevitable as long as it is directed by economic pressure as at present. The better sons of the Ozarks can find it worth their while to remain only if defects in the present economic adjustment are found and remedied. If nothing of the sort happens, the drainage of this best blood will continue permanently and will express itself in the decreased productivity of the area. The movement is only in slight measure similar to the release of a portion of the population by improved methods of production such as has been the case with power farming in the prairie states. The emigration now in progress indicates the beginning of actual economic decline in numerous sections, if not yet generally.

It does not follow from the foregoing that the people of the Ozarks live in want. An initial period of no inferiority has been succeeded by a century in which contrasts with surrounding regions have grown sharper and less favorable. The consciousness of such an unfavorable comparison is in the main a matter of recent growth. The drifting away of the most productive part of the population is following naturally and constitutes a threat of increasing seriousness.

The half of Missouri that lies in the Ozarks possesses less than one sixth of the wealth of the state. In terms of population, however, the situation is much more favorable. Valuations returned by the State Board of Equalization for 1918 are approximately three hundred and twenty dollars per capita for the Ozarks, as against five hundred and seventy-five dollars for the entire state. In this calculation there are included in the Ozarks such prosperous centers as Springfield, Jefferson City and Cape Girardeau, as well as the mining regions of Joplin and the St. François district. On the other hand, the largest area of rough hill country in Missouri,[3] embracing a half dozen counties of extremely low total valuations, shows per capita valuations nearly equal to the average of the whole Ozark Highland. Two of the roughest counties in the Ozarks,[4] exceed the per capita average of the Ozarks by one eighth. The explanation is that in the rough hill areas the hills are almost entirely non-agricultural and the population is concentrated on reasonably good valley lands. Also, in a comparison of the Ozarks with the remainder of Missouri it must be remembered that St. Louis holds a full third of the wealth of the state, and that St. Louis and Kansas City together account for nearly one half of all property. According to per capita of population, the valuation of the Ozark region is easily two thirds that of the remainder of Missouri if the two principal cities are eliminated.[5] Certainly no general condition of poverty prevails.

If the region gives an impression of poverty to the casual visitor the explanation must be found in the simplicity of the habits of the people and in the even distribution of wealth. Few men possess much more than their neighbors, but want is not much more common than is wealth. There are a few poverty spots on submarginal farming lands, which are not in the supposedly poorest regions, the rough hill sections. Too much emphasis has been given to the idea of poverty in the Ozarks. The parallel between the living conditions of the Ozark native and the mountaineer of Kentucky and Tennessee is not at all close and even less so is that with the poor white of the southern Coast Plain. A degrading environment can be shown only for very limited tracts and these are for the most part outside of the cherty limestone regions. The trouble

[3] The Courtois Hills region of the volume, *op. cit.*

[4] Carter and Shannon counties.

[5] The figures are compiled from the Report of the State Auditor of Missouri for 1917–18.

lies in the stagnation of life, as expressed by the lack of development of new opportunities, and in part in an incipient contraction of standards of living because an outworn economic system is still followed.

The economic system has been altered only in minor ways from that which was in force at the time of early settlement. The average inhabitant of the Ozarks is still an unspecialized small farmer, rather than a farmer following an intelligent practise of diversification. Of labor income he knows nothing, and commonly has none. The pursuits which he follows give little opportunity for the accumulation of a surplus. The aim of labor is hardly commercial, the labor being expended directly toward the sustenance of the family. The condition is characteristic of primitive groups. The economy is based primarily on agriculture, but agriculture is typically only a partial means of subsistence.

Corn is the dominant crop. It is grown on thin uplands and on stony hillsides as predominantly as it is in rich bottoms. It is produced not only with almost total disregard of the character of farming land but of the size of yield as well, simply because it has a larger direct utility to the individual farmer than any other crop. It feeds the family, and the horses, cattle, and hogs. It will keep without means of storage. It will grow in the most poorly prepared ground. It yields the largest returns of food per acre cultivated. Also it was grown by the first settlers as the main crop and their descendants are following the old traditions. From the standpoint of commercial development, from every standpoint in fact, except that of a farm functioning as a self-sufficing unit, corn is grown very much in excess of the best interests of the region. Except in the bottoms, the land has been much too heavily "corned" for years and increasing difficulty is experienced in maintaining yields. But from the highly individualistic viewpoint of the native it is the most suitable crop for his social system or the lack of such a system.

In addition to being a corn-farmer, the resident of the interior Ozarks is normally a live-stock producer. He could not be designated, however, a rancher, breeder, or feeder. The form of the industry also goes back to first frontier, and was responsible in large measure for pioneer immigration into the Ozarks. The plateau shreds, even where they were only narrow ridge-tops, were covered originally with grasses. They are still commonly called prairies. On these live-stock grazing was instituted at an early date. Fires were set habitually by

the pioneers to replenish and extend the grazing lands. These fires extended the grass lands at the expense of the forests. Grazing itself extended into the forests as the population increased. Fires and long-continued grazing in the forests have interfered in many districts with the growth of seedlings, sprouts, and other undergrowth, and have resulted in a forest-floor covered with grass and weeds. The ridge-tops are now converted almost entirely to plow land, and grazing has therefore suffered a restriction to the forested areas, which are nearly equivalent to the hillsides. This poor, volunteer pasturage among the trees is incapable of improvement and by reason of long-continued grazing at all seasons has been steadily deteriorating. With the elimination of the natural grass lands the cattle industry has largely passed into the condition of a relict industry.

Hogs fare much better, being essentially forest animals, and finding here a varied and often good mast of acorns, nuts, berries, and roots. The razor-back animal is an unimproved, but successful adaptation to his peculiar environment. Sheep are very few, because, roaming at will, they are subject to serious danger from dogs, who are also unrestrained. Turkeys thrive under a similar life, in which they partially revert to an undomesticated condition.

The keeping of stock bears virtually no relation to the ownership of land. All land that is not farmed or in fenced pastures constitutes the free range. This consists in part of large timbered holdings belonging to absentee owners. Many large tracts are crossed by the property lines of local farmers but are not shut off by fences. The result is that stock ranges widely through the woods, for most of the year without attention. As a consequence the struggle for a bare existence keeps it in poor flesh. Even more serious is the reproduction by accidental breeding from scrub sires. Against the ease of this method of live-stock raising are to be set the very low quality of the product, the decreasing carrying power of the range, and the uncertainty of the returns.

The average farm contains more wooded land than it does cleared land. This is true even of the border regions, with the exception of the Springfield area. In the hill counties there are likely to be three or four acres of timbered land for every acre cleared, in each farm. In addition there are large timber tracts that are not included in farms. Timber products therefore are an important item in the economy of the native. These items are produced and marketed principally by the

farming population, not by lumbermen. The principal products are ties, and in some localities, cord wood and mine props. The important stands of white and post oak are especially valuable for ties, of which the aggregate production is large. The principal winter occupation is the cutting and hewing of ties. They are then hauled out over the frozen roads, or later rafted downstream during freshets. The industry is pursued with particular zeal because, among a group of part-time occupations that yield little for sale, it provides cash returns. The very great increase in the price of ties has lately stimulated strongly the search for suitable tie timber. There are few sections in which the trees available for this purpose are not fast decreasing, and the cutting of such timber has proceeded into the most remote localities.

Numerous minor and incidental occupations are followed also for their cash returns or for purposes of barter at the country stores. Here belong the digging of roots such as ginseng, golden seal, and blood root, hunting and trapping for skins, and the digging of minor minerals, such as tiff (baryte) and fire clay. In most cases, increased prices have made good a decreasing supply, but the supply of these auxiliary resources is in general markedly declining.

The Ozark farmer in short is following a system of production that is in reality simply exploitation. In virtually all of his occupations he has passed the period of largest volume returns, although aggregate values may still be mounting. Increased prices can not permanently resist the actual decline that is threatening the productive efficiency of the individual. Exploitation is a mark of the frontier and the perpetuation of the frontier is recorded strikingly in this general condition.

The reasons for this peculiar fixation of a frontier are not difficult to determine. In the first place, to a degree not equaled elsewhere in the Middle West, the people of the Ozarks are descended from frontiersmen. The parent stock represents a certain aversion to orderly and sustained endeavor and therefore to intensive production. To what extent the trait persists as a hereditary quality is not known, but, given the opportunity, the native of the Ozarks apears to be about as frequently successful as most other Missourians or Arkansans. The difficulty with his ancestry seems to lie not so much with physical inheritance as with the traditions among which he is brought up. At the least, he has not inherited the agricultural experience and interests with which his neighbors of the plains are surrounded. He goes back to a more primitive ancestry.

The biggest element in the retardation of Ozark life is the isolation that the surface has imposed on the inhabitants. A chain of rugged hill regions is thrown about the interior plateau and constitutes a veritable entanglement of obstacles against any approach from the lines of communications that follow the Missouri, Mississippi, and Arkansas rivers. Even more significant than the exclusion of the outside world is the detached manner of living of the people. Valley is separated from valley; valley settlement is out of touch with ridge settlement; often family is isolated from family.

The simple result is that the isolation has kept social and economic progress at a snail's pace. The people were primitive in their condition when they came, they are nearly as primitive now. Without strong social instincts and training to begin with, how were they to achieve common interests, common opinion, and common effort? For the economic problem of the Ozark Highland is after all social in its fundamentals. The difficulty that the people experience in getting to market is less serious than their failure to get together. There has been no substantial economic development because topographic isolation has maintained successfully the social anarchy of the frontier. It is the solitary position of the individual, rather than the poverty of the soil, that at bottom is at fault with the Ozarks. The so-called political conservatism of the Ozarks is well known. It has its full social and economic equivalents. The individualism is almost static. The individual produced under this system is bound down by it. How can be he intelligent enough or sufficiently strong to reshape the outworn economic order? There are adequate possibilities for the inhabitants of the Ozarks, but these can be realized only by fairly advanced cooperative effort. Of cooperation the native knows nothing beyond the relief of a neighbor in trouble. The stakes of the region are not such as to tempt extraneous capital and the social order therefore has received no alteration from the outside. Unless the region is to become decadent, the isolation and its resultant excessive individualism must be broken down, and this must be done by the governments among which the highland is divided.

The first corrective measure must be improved means of communication. The construction of additional railroad lines on the long shreds of plateaus is a simple matter. However, their returns for a considerable period would hardly be sufficient to tempt private capital. Unfortunately also several Ozark branch lines have been abandoned lately. Similar expe-

riences in other sections of the country indicate that the time is probably past for the construction of branch line railroads.

The main wagon roads follow ridge tops. Their location is determined by low cost, freedom from floods, and freedom from erosion. They are passable throughout the year, but serve directly only the settlements on the ridges. Over large sections these settlements are not as flourishing nor as promising for future developments as the valley settlements. It is notorious that the traveler on the main roads sees very little of the better land. The ridge roads are separated from the valley farms by steep hills. Connection between the two is made by rough and often badly washed side roads. The secondary roads that follow the valleys are subject to flooding with every freshet and are often washed out. Fords are innumerable, bridges few. The location of roads was determined by the easiest lines of travel. The adjustment is complete so far as it goes, but it is based on unimproved roads that are simply traces worn by travel. Permanent roads are needed in the valleys. Their appropriate position would be on the lower flanks of valley slopes out of reach of floods. Roads of this type can be had only by moderately costly construction.

The road situation is so bad that it is almost impossible, and consequently a number of counties are now undertaking road building by bond issues. The present policy of state aid is contributing important funds indirectly from the wealthier portions to those Ozark districts that desire to avail themselves of help. There is an unfortunate tendency, however, to follow the locations of roads as they have become fixed by pioneer custom and to superimpose the improved road on the all-weather trail. In the building of roads there is needed not merely the technical skill of the road engineer, but a close economic analysis of the distribution of good farming districts and their relation to road facilities.

The live-stock industry as a cooperative enterprise, in place of its present individualistic form, is indicated as the dominant ideal occupation of the future. (1) Partly as the result of the long period of erosion, partly because of the powerful aid of solution, valley bottoms are extraordinarily numerous and large, even among the roughest hills. Their rich soils, annually reinvigorated by floods, are suited to continuous cropping to corn. The only argument for rotation of crops on these lands is the elimination of diseases of the corn plant that may find lodgment in the ground. On the valley lands, soy beans, velvet beans, cow peas, clover, and alfalfa also grow very well. These

lands may grow important quantities of high-grade stock feed. (2) Cheap grazing lands are available in large amount. The lower valley slopes, the slip-off slopes of intrenched meanders, benches on the sides of valleys, and the smaller ridge-tops especially are well suited for hay and pasture. Many ridge lands are being cropped that should not be under plow. Their thin clay soils are unprofitable for grain growing, but will produce good grass, as they once did. In connection with a really profitable live stock industry these ridge lands would be employed most profitably as permanent grass lands. At present the most indigent larger group of farmers in the Ozarks is found on ridges of this type. Very valuable forage grasses and clovers are in process of naturalizing themselves successfully, and with some protection will improve the quality of the forage markedly.[6] It is to be remembered that the strikingly poor quality of present pastures is the result of over-grazing and utter lack of care. (3) The mild climate and abundant rainfall extend the grazing season almost to nine months. Woods, cliffs, and coves provide partial winter shelters, too often the only ones supplied for the stock. Housing and winter feeding, however, are not serious problems. (4) Probably no other section of the United States is so well supplied with springs. Throughout the limestone country magnificent springs of cold and pure water abound along all valleys. The assertion is often made by a farmer that he has a good spring in each pasture.

Cattle, hogs, and sheep all have their place on the Ozark farm. (1) The first step in improvement of conditions is also the easiest. It consists in the elimination of undesirable sires. Even this is a community enterprise, both as to the purchase of pure-bred males and the disposal of the undesirable males. The custom of allowing stock to range about in the forests is not likely to disappear soon, nor is it necessary if the control mentioned is exercised. (2) The Ozarks constitute potentially a great dairy country, undeveloped at present except for certain border regions. The absence of dairying is due to the serious difficulties in marketing and the utter lack of experience of the people. Cheese making is largely independent of shipping facilities and could be undertaken even in remote valleys. A geographical parallel is to be found in the Carolina mountains, the physical conditions being somewhat better in the Ozarks. In remote Carolina valleys a remarkable success has been scored in the past few years by cooperative cheese fac-

[6] Lespedeza, sweet clover, blue grass, and Bermuda grass.

tories. The conditions of living in many an Ozark valley could be transformed similarly under proper direction. (3) A successful swine husbandry could be worked out by combining farm crops with mast and introducing a suitable breed, as for instance one of the forest-bred English varieties of bacon hogs. No attention is being given to the preservation and increase of the kinds of trees that are most productive of mast, for exploitation does not heed any demand except that of an immediate profit, even if small.

For every acre in the Ozark that is in any way improved there remain two acres in the woods. In that third which is classed as improved land is included a good deal of rough, stumpy pasturage with a partial stand of timber remaining. In the hill regions the amount of improved land is very small. It is least in Carter County, with only nine per cent. of its total surface improved. The wild land for the most part is covered with oak timber, cut over repeatedly. The majority of the timber to-day is small, and where grazing has not been heavy the second-growth is dense. Potentially, it is one of the two most important stands of oak timber in the United States. The removal of the older trees and the neglect and injury of the second-growth are resulting in rapid deterioration. In many places even the acorn mast has been destroyed by the cutting of seed-trees. Grazing has done much injury to the forest floor, with the result that the growth is less vigorous than climate and soil would indicate. The good timber is nearly gone, but the land on which it grows is essentially non-agricultural. Little of it has been laid waste by fires. It is probably no exaggeration to estimate that fully half of the Ozarks can never be good for anything except the growth of trees. It is not growing good trees now and soon will be virtually non-productive. Missouri is facing the idleness of a fourth of its total area without so much as a forestry office in the state to take notice of the situation. Arkansas is in no better condition. The problem of restoring these forests to a productive condition must be worked out in cooperation with the farmers who own a good half of the forest land and who will continue to be dependent in various important ways on forest products.

As yet there has been surprisingly little soil destruction in the Ozarks. Many Ozark streams are quite clear, even in flood. Gradually land clearing is pushing into the margins of the 'breaks' with no profit to the farmer and with the threat of grave damage to the countryside. These dangerous clearings for the most part are made by ridge farmers who need addi-

tional acreage and are taking a chance on the upper slopes of the valleys. The clean cutting of timber, fortunately, has not been much practised, as it is of no advantage to the farmer. Land clearing has nearly reached the limit of safety, and will shortly pass it unless the economy of the area is readjusted. The states concerned are still in good season for the introduction of land policy that will save the forests and their water power, protect farming development, and relieve the taxpayers from the burden of supporting large areas of idle lands.

Roads, live stock and a forest policy point the solution to the stagnation of Ozark life. There will be other forms of development, which even now are under way, but these three are the fundamentals. Water power will be developed in increasing amounts, but its benefits will go primarily to the cities that are situated about the Ozarks. Tourists will discover increasingly the merits of a recreation in Ozark streams, but it is to be hoped that the native will not have his simple hospitality spoiled by summer visitors. Fruit growing has received much publicity and there are a number of good, established fruit districts. Elsewhere, shipping facilities and organization present difficult problems. Thin soils and steep slopes are antagonistic to permanent orcharding. Missouri possesses in her loess lands a much more productive fruit soil, much better located than the interior Ozarks, and developed for orcharding to only a very small extent. It would probably be beneficial to the development of the Ozarks to place relatively less emphasis on the possibilities of fruit.

Help is needed for the Ozarks. The condition of the people is such that they can not well help themselves. They are standing singly, uninstructed in their larger possibilities. It is a numerous population that needs to be made more effective, before degenerative selection destroys its best capacities. State investigators here and there are carrying on inquiries into Ozark problems, but the work is largely lost because advice is given in the main to those who know how to call for it. What is needed above all is a policy of development for the region as a whole which will recognize the unity of the problem, not its fragments. If the states involved have the patience and the wit to plant the community spirit in the valleys and on the ridges of the Ozarks, the native will find in himself and in his environment the resources with which to develop a permanent constructive economy in place of the present self-destructive system handed down from frontier ancestors.

GIANT SUNS[1]

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THE new secrets wrested from the stars have chiefly come, not from the increase in size of telescopes, but from the new appliances attached to them, such as the photographic plate, the spectroscope, and by this time many others. The lines in the spectra of stars tell us what the stars are made of, how they may be classified accordingly, how fast they are moving, how bright they really are (this is an amazing recent discovery), and by inference how far away, and may yet have other surprises in store. For the moment we are chiefly concerned with the classification. The Harvard system gives us a number of classes denoted by the capital letters O B A F G K M R N. The fact that the order is not quite the same as that of the alphabet represents a revision of early ideas, chiefly due to the gradual accumulation of intermediate types, which make a nearly continuous series.

Now a series of stars in order is probably a representation of growth; just as the growth of trees may be illustrated by selecting various stages from the same wood, an illustration originally given by Sir W. Herschel. But we have seen a tree grow, and we know independently that it grows up from the acorn through the sapling to the giant oak; while we have not had time to see a star grow and were thus in ignorance whether the changes are from B towards M or from M towards B, though by this time we have an immense number classified. The classification has been largely the work of an American lady, Miss Cannon. I am told that there is a man who can deftly straighten rifle barrels—he gives a glance along the barrel, a tap with a hammer, and lo! it is straight. His value is recognized at some £15 a week. Miss Cannon has the same deftness with spectra—but I fear that (to judge from the report of the Board of Visitors of Harvard Observatory) her great skill is not so appropriately rewarded.

Now it is obviously important to find out, if we can, which is the direction of a star's growth, and we seemed to have an im-

[1] From an address before the Royal Institution of Great Britain.

portant clue when the spectral classification was connected with the temperature of a star, or rather its *surface* temperature, which is all we can get at. The outside is the coolest, just as the edges of a plate of porridge are the coolest, as most of us have learned by early and rather painful experience. And yet the outside of a star is hot enough. The temperature is again estimated from the spectrum, though this time not from the lines but from the relative intensities of the ends, and the O B A end is undoubtedly hotter than the other. We may give as illustrations 15,000° for B, 5,000° for G, and 2,500° for M. Does this settle the matter? We know that there is a general tendency for all bodies to cool which points to the direction C B—M N as the order of events; but it was also known that under the stress of gravitation a star might rise in temperature, in which case the growth might be the other way. Still the former alternative commended itself more generally; and when Professor W. W. Campbell found that the velocities of stars (also determined with the spectroscope) were smaller for type B than the type M, the facts were interpreted to mean that a star moved more quickly with advancing age (because M stars were older than B). The idea that the life of a star was spent in passage down the series O B—M was indeed pretty firmly established at the time when the revolution came.

The revolution began with the advent of a young American research student, Mr. H. N. Russell, to Cambridge in 1904–6. It is to the credit of Mr. A. R. Hinks that he made so much of this brilliant young student, setting him on the way to determine the distances of a number of stars by photography with the instruments which he (Mr. Hinks) has spent much time and labor in perfecting. This was the first element in his success. The next was that on his return to America he got from the Harvard Observatory—that storehouse of astronomical facts—the spectral types of his stars; and combining these with the measures of distance (which told him the intrinsic brightness or luminosities of the stars) he found that stars of the same spectral type M fell into two distinct groups separated by an interval. There were very bright stars, now called Giants, and there were very faint ones, now called Dwarfs, but none of intermediate stature.

The same was true in minor degree for stars of other types, but as the B end of the series was approached the gap gradually disappeared much in the way that the gap between the legs of a stepladder gradually lessens as we approach the top. Indeed Russell's diagram of his results is very like a stepladder, the top representing the B stars followed by A, F, G, K, M, in

descending order, and the gap between the two legs of the ladder representing the difference in luminosity, as the intrinsic brightness of a star has come to be called. Russell brought this diagram with him when he came to attend the meeting of the Solar Union at Bonn in 1913. It is sad to remember the occasion, for the most friendly relations seemed to have been permanently established between the various nations assembled. We remember with especial regret the trip on a great steamer on the Rhine which ended the meeting, and, alas! was the end also of our hopes of a permanent friendliness, for before the year had passed the Great War had shattered them all. It was on his return from Germany through England that Russell showed us his stepladder diagram at the Royal Astronomical Society, and expounded his views on the evolution of a star, which were that its life began at the foot of the upright leg, the ascent of which signified that the star was growing continually hotter and changing its spectral type meantime from M upwards towards B, that at B the increase of temperature was arrested and after a time cooling began carrying the star down the inclined leg of the ladder through changes in the reverse order. The only weak spot in the evidence arose from the small number of observations. To determine the actual or intrinsic brightness of a star we must know its distance, and there are not many stars of which the distance can be easily measured, and though Russell had himself increased the number, the total was still not large. To get further evidence he had recourse to indirect estimates of distance, especially those of clusters of stars. We have lately become more and more aware of the association of stars in clusters represented by their common movement, somewhat in the way that the movements of a flock of birds migrating from one place to another are associated. If we may accept this evidence, and if we can determine the distance of any one star in the cluster, the distances of the others can be inferred. In Russell's skilful hands this evidence was collated and found to strengthen his conclusions.

Let us pause here for a moment to reflect on the inherent probability of the suggestion. Is it not after all much more likely that a star first rises in temperature and then falls rather than that it should be permanently either rising and falling? Now that the idea has been put forward, and that there seems to be not only good evidence of this change in the sky, but, as we shall presently see, also good theoretical reason for it, we wonder why the idea was not the most natural one to adopt from the first. But curiously enough it was not the one adopted by astronomers, with the notable exception of Sir Norman Lock-

yer, who made the same suggestion as Russell's (though on different grounds) many years before. May I give a crude illustration from our ordinary life of the mistake that was made by many of us? It is as though we had taken the amount of hair as an indication of the age of a man. In very early life the amount of hair is small, it increases with age up to a certain point, but then it begins to decrease until a very old man often has as little hair as a newborn baby. We could give Shakespeare's Seven Ages of Man according to the amount of hair in the same diagrammatic form as Russell's stepladder, beginning with the baby at the foot of the upright leg, ascending to the man in middle life with maximum hair (corresponding to the maximum temperature), and placing the greater ages down the inclined leg till we arrive again at a bald pate. Shakespeare reminds us with his phrase about the voice "turning again toward a childish treble" that not only the hair but the voice goes through changes which show a reversal after middle life. We were practically confusing the baby stars with the old man stars until Russell called our attention to the fact; and now it seems quite easy to make the distinction. But there was some hesitation before the new views were accepted at all, chiefly on account of the lack of sufficient measures of distance, which left room for doubt. Recently the evidence has been reinforced in a remarkable way by a totally new and unexpected method for inferring the distances of stars, due to Mr. W. S. Adams, of the Mount Wilson Observatory in California. His discovery is that if we have two stars, one of which is very bright intrinsically and the other faint, but both of the same spectral type, we can find two lines of the spectra which have different relative intensities: let us call them A and B. In the bright star A is more intense than B, in the faint star B will be more intense than A. Now observe that this difference will persist however far we may remove the stars from us. By altering the distances we may make the brighter star *appear* the fainter, but we can pierce its disguise by noting simply that the line A in the spectra is the more intense, so that if the star *appears* faint we see at once that this must be due to its greater distance. In fact we can infer the distance from the relative intensities of the lines A and B, so that Adams has really given us a new method of inferring distances. The new method has the further advantage of requiring far less labor than the old method of parallax; in fact, when once the spectrum has been photographed the further labor required is quite small, so that by this time Adams has been able to give us the luminosity of hundreds of new stars, and by this overwhelming evidence confirms Russell's results derived from merely a few.

In addition to this confirmation by new observations we have had an independent confirmation by the brilliant theoretical work of Professor Eddington, who has attacked the problem of the life of a star mathematically. He supposed a mass of gas first of all to be simply under the action of its own gravity. It will consequently contract, and owing to the contraction will rise in temperature; but Professor Eddington soon found that this simple hypothesis would not answer—it led him to impossible results. Clearly something else beside gravity must be at work, and he was driven to the further hypothesis that the *radiation-pressure* inside the star played an important part in its history. Radiation-pressure (or if we like to call it so, light-pressure) is what makes the tail of a comet. As a comet approaches the sun it begins to feel the effects of the fierce light, which is known to be able to drive away very small particles from the head of the comet, much as we can blow away chaff from wheat. In consequence of this action the small dust-like particles which may exist in the head are believed to be driven outwards to form the tail. But this force is not merely in existence on the outside of the sun, it permeates its whole body. A particle inside the sun is of course receiving radiation-pressure from all its surroundings, but the pressure will naturally be greater on the hotter side, *i. e.*, on the side of the sun's center. Working out the problem afresh with the addition of this new factor, Professor Eddington has obtained results which agree satisfactorily with the observed effects, and indeed the closeness of the agreement is startling. He is able to utilize the fact noticed earlier in the acticle, that the masses of the stars are not very different, so that it is easy to take three representative cases—let us say one in which the mass is equal to that on our sun, one in which it is 5 times greater, and one in which it is 5 times less—and by following these three cases in detail he can show the distinctive features of different stars. Briefly, the stepladder is highest for the star of greatest mass, which may get hotter and hotter until it reaches type O; a star of intermediate mass like our sun is arrested at a lower height, and may not reach higher than type F, or at best A, before it begins to fall down the inclined leg; while a star of small mass may reach no higher than type K at any time. The golfers in the audience may be reminded of their handicaps. Those who are destined to be scratch players (probably, however, *not* because of their great mass) improve very rapidly until they reach the highest pitch of excellence, and it may even be only in old age that they begin to travel downwards; but then there are others of long handicap, who although they may improve a

little at first never get beyond the fatal 18 at their best, and on whom declining years soon begin to leave their mark.

One of the most remarkable suggestions of Professor Eddington's work gives a reason for the close resemblance in mass of the stars. There is a certain mass for which the radiation-pressure pressing outwards nearly balances the force of gravitation pulling inwards, and it is clear that for stars as large or larger than this a break-up sooner or later is to be expected. This assigns very obviously the upper limit to the masses—we can easily see why there are no stars larger than a certain limit. But how about the lower limit? Are there no stars *very* much smaller than this? Certainly there are: we are living on one of them. Our earth is smaller by some thousands of times; but then it is not a star in the full sense, for it is not shining with its own light. If it did ever so shine the light must have been feeble at best and have only lasted for a very short time. There may in fact be many small stars, but *we do not see them*, and accordingly have not reckoned them in saying that the masses of the stars are closely similar.[2]

I can not give you a better idea of the value of Professor Eddington's work than by quoting a few words from a letter written to me by Mr. Russell, again specially in response to a request mentioning this lecture: "What appeals to me as the big thing is Eddington's work on radiative equilibrium (MN 77, p. 16 and p. 596). The importance of this can hardly be exaggerated; it is not too much to say that it is the first rational theory of stellar constitution."

Eddington has in fact given us a rough attempt at tracing the history of a star of given mass. By way of illustration let us consider our own sun. He is now a "dwarf star," on the descending leg of the ladder, of spectral type G, and with a surface temperature of about 5,000° C., and an absolute magnitude 5.1. Looking back into the past he was at one time much hotter and of type F, and probably never rose much higher than this on the ladder. Before that his history lay on the ascending leg, and there was a time when his spectral type was just as at present, but his absolute magnitude was near zero, five magnitudes greater than at present. This means that the total light was 100 times greater than now, and since the surface was in a similar radiative state, it must have been 100 times more extensive. The diameter of the sun was therefore ten times the present diameter—ten million miles instead of one million.

[2] On reading this again I realize that it does not do full justice to Eddington's suggestion for the lower limit. He shows a definite difficulty in the formation of small stars.

Where our little earth may have been at that time we can scarcely conjecture, but supposing for a moment that we had been able to regard the sun in our present conditions, he would have taken nearly an hour to rise instead of a few minutes; and when risen, his disc would be ten times as great in all directions—a "giant" sun indeed! And yet this magnification of 10 to 1 is only modest compared with the extreme possibilities.

We set out by the recollection of Jack the Giant Killer, but our road has led us rather to think perhaps of Jack and the Beanstalk. We have climbed up to Giant Land, the land of the giant suns, not by a beanstalk, but by means of the trembling rays of light, a ladder which does not grow upwards from our earth, but is let down to it by the giants themselves. "Fee Fo Fum!" said the Giant, "I smell the blood of an Englishman." In our analogy the giants have been invaded, not by an Englishman, but chiefly by an American; but at any rate we have the satisfaction of reflecting that his work began in Cambridge when he was a student, and that at the end of it there has emanated from Cambridge this brilliant confirmation by Professor Eddington of which the discoverer has himself expressed such generous appreciation.

THE MEDICAL AND ALLIED PROFESSIONS AS A STATE SERVICE

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ALTHOUGH preventive medicine is state-controlled, curative medicine is still the same unorganized, happy-go-lucky competition it ever was. Some thinkers assert that the time has now come for the applied science of curative medicine to be taken over by the state and organized into a system. Both departments—preventive medicine and curative medicine—would naturally be under the Department of the Minister of Health. Of course, there would be but one portal of entrance with one uniform standard of examination into the departments of curative state medicine and of preventive state medicine. This one standard of entrance would remove many existing anomalies. The doctor would then be to the whole public what the club doctor is now to a section of it. He would attend to the cure of cases exactly as the department attends to the prevention of cases. He would be a state official, salaried and pensioned as such. It is an anomaly that if your child has scarlet fever, while one aspect of the case can be properly taken in hand by an official only of the one aspect of medical science, the other aspect of the case has to be left to private medical enterprise. I should be able to summon a state-paid physician for a case of broken leg, pneumonia or insanity just as I now am able to do in a case of measles or diphtheria. This would, of course, lead to the whole problem of medical treatment being solved by being state-controlled. The great hospitals with their vast, beneficent out-patient departments would become state institutions just as prisons, penitentiaries and asylums are already.

There is no valid, other than a historical, reason why the scientific cure of disease should not be a state service as much as the scientific prevention of disease. The Indian Medical Service affords us an example of a state-managed medical service; it shows us how such an organization might be so vastly extended as to become imperial. Promotions, disability pensions, retiring pensions, etc., would be arranged for as in the Civil Service. The state would, therefore, also logically

take care of the problem of research in medicine, and, directing it, coordinate the isolated efforts made in it in the manner most beneficial to the public weal. In the United States, private enterprise has endowed medical research in a truly magnificent manner. Private endowments could still be given for medical research within the British Empire, but it would be well if the directing of medical research were made a responsibility of the state. Much of it is even now, as for instance, the splendid work on plague done in India, and the work on cancer in London. The medical researcher is a medical man no less than the general practitioner; he is only more specialized; he should equally be a servant of the state.

In an article by Colonel J. T. K. Maurice, C.M.G., entitled "A Vision of State Medical Science," which was published in *The Hospital* for November 9 and 16, 1918, the matter is put thus:

> Let us say in sickness the best advice and treatment is to be placed within the reach of every man, woman and child of the community . . . thoroughly efficient measures to ensure the good health of the community are to be devised and properly carried out. . . . Surgical and medical knowledge have stridden forwards so rapidly in the last few decades that the means of diagnosis and treatment to the hands of the medical profession are far more elaborate, far more efficacious and far more costly than they were heretofore. The guesswork of the old clinical diagnosis can be supplemented by X-rays, chemical tests, sera diagnoses and so forth, and an accuracy, a certainty, attained that was formerly impossible. . . . These elaborate processes are expensive, many require special buildings, costly apparatus, and men of long experience and special skill to apply them; and so under present circumstances they can not always be brought to the service of the sick. . . . Sera and vaccines, new powerful drugs, anesthetics, and antiseptic surgery, have brought about a wonderful change. But treatment by these means is an expensive matter, and entails the employment of highly skilled nurses . . . so the wages of nurses have risen and rightly. . . . The total result of all these changes is that the expense of making an accurate and fully confirmed diagnosis and of giving thoroughly sound treatment and nursing is so high that it is unattainable to most of the population except by charity. It could, however, be obtained by cooperation and mutual assurance, either by voluntary association or by submission to the necessary taxation. Either is better than the pauperization that comes of charity. The ideal is a healthy race, each man paying for himself or paying his share of the cost of maintaining the common health.
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> Sanitary science in all its wide ramifications has not yet come into its own. . . . In some large towns a good deal is done to preserve health by preventing disease. But the important step of thoroughly educating the mass of population has not yet been taken. All must learn that a healthy race implies parents without inheritable defects, strong and healthy in body and mind by gift of birth, implies restraint of the passions, avoidance of venereal disease, proper selection of foods, exercise

in fresh air, avoidance of overcrowding, good ventilation of houses, healthy occupation, healthy amusements, and happy occupation of leisure instead of unwholesome pleasure. One of the first needs of health is to learn wisely to use leisure. All this must be taught. A state medical service should be an educating service. If a state medical service were formed, its functions should be executive and advisory. It should carry out measures to prevent disease, but the measures would emanate from legislative bodies. It should advise parliament, county councils, corporations and other public bodies. It should suggest legislation. It should treat the sick. It should educate the community in the ways of healthy living, and it should administer itself.

Before we descend to the details of the working scheme of the state medical service, let us consider the exact point we have reached in what might be called the evolution of the medical profession from the individualism of the physician of the middle ages to the somewhat socialistic position which he occupies to-day.

If we go far enough back we find the doctor to be physician, surgeon, anatomist, botanist, zoologist and pharmacist, all in one. In the eighteenth century one single professor often taught botany, anatomy, surgery—and what physiology there was. But now he has evolved or been differentiated into at least six persons—anatomist, botanist, surgeon, pharmacist, pharmacologist and physiologist. Just as in the village the same shop is post-office, grocer's, tobacconist's and various other things all in one, in the great city it is represented by half a dozen distinct establishments.

There is another feature of modern civilization, especially in Christian countries, namely, the rapidly growing solicitude for the health and welfare of *sections* of the community as distinguished from the individuals in it. Previously, the individual physician treated or cared for the individual patient, and there his activities ended; to-day the public conscience is occupied with problems about the welfare of *group* or *sections* of the public; with soldiers and sailors as such, boys under fourteen as such; with those infected with venereal disease or with phthisis or those who are in prison or are destitute. Specific groups in modern society are being studied, examined, educated, treated and cared for generally in such a way as to show that the question, "Am I my brother's keeper?" has been very fully answered in the affirmative. Thus we have societies for ameliorating the vital conditions of Thames bargemen, policemen, postal officials, illiterate immigrants, ex-convicts, seamstresses, indigent gentlewomen, and many other groups in the community as such.

It is the day of a sanitarily minded humanitarianism; the cruelty of the eighteenth century—of the Hogarth pictures, for instance—has gone, we hope, for ever. Society with a big S used on Sundays to make up parties to be entertained by the howls and antics of maniacs chained behind the bars of cells in Bedlam, as the Hospital of St. Mary of Bethlehem was called. The eighteenth century was cold, artificial, antipathetic and cruel, but Hales and Howard and Elizabeth Fry and Florence Nightingale became pioneers in that movement towards modern sympathy not so much with the distress of individuals as with the sufferings of social groups.

At the present time it is the health of *sections* of the community that is the concern of governments: for instance, the health of miners and of workers in potteries and of woolsorters, as such. We have become communistic, institutionalistic, socialistic, in the very best sense of that word. The instituting of a state medical service is entirely in harmony with the general trend of this ever-widening humanitarianism, for it means that the health of the nation is to be looked after in a manner similar to that according to which any other national concern is managed—war, the law, trade, agriculture or fisheries. We have officers and ministers for these affairs of national importance: it is suggested that we have one for the national health, a concern undoubtedly more important than any other.

The great war has made it very clear to us that far larger numbers of the population are physically infirm than we had any idea of. Even if all the military rejections were not sustained on revision, the number of men under the normal in health is alarmingly large. Now all this ill-health means inefficiency not only from a military point of view, but from every other. But the war, happily, has shown us something else, namely, that the applied science of national state medicine or hygiene could, by the working of a well thought-out organization, prevent the outbreak of those very diseases which in all previous campaigns proved more disastrous than wounds or bullets. In illustration of this, the following figures may be quoted: In the South African War the ratio per cent. of those dying of disease to those dying of wounds was as 65 to 35. In the Great War the same ratio was 5.14 to 94.85. This revelation is a great triumph for preventive medicine; it shows what, given a fair chance, it could achieve under the most disadvantageous circumstances. If all this prevention of disease

and this conserving of human life could be carried out under the most distracting conditions of the most inhuman war in the history of this planet, what could not state medicine achieve when working under the sane conditions of that normality called "peace"?

A national weakness must be met by national strength; a national disease by a national remedy. What were, then, briefly the factors that made for hygienic success in the war? First, expert knowledge and the services of relatively few experts organized for the benefit of relatively many people. This is precisely the principle we advocate being applied on an imperial scale. The war was won by cooperation, and the more speedily as that cooperation was the more perfect. Why should this principle not be applied under peace conditions? If fighting and the law are considered such honorable state services, why may the equally noble profession of medicine not be so considered? Surely fighting and destroying are not the only outlets for patriotism. I submit that it is as patriotic to save the lives of the children of a state as it is to take away those of its enemies. It does not invariably require great skill, though it may require great courage, to take away a life; it sometimes requires all the resources of science to save one. As an old friend of mine used to say: "Any fool can burn my shirt; what I want is some one who can iron it." While the highest expression of the patriotism of a day that is dead was to be proficient in the art of destroying life, may we not hope that the highest form of the patriotism of the day that has just dawned may be the attaining to the highest proficiency in the science of preserving life?

This state medical service is something more than merely organizing the medical profession as it exists at the present moment; it is nothing less than the creation of a state service for the explicit purpose of maintaining the highest health of the highest number of the citizens of our empire, and therefore systematically preventing the outbreak of diseases amongst them. This new service would conserve the health of all our social groups; the navy, army, the merchant marine, civil servants, inmates of prisons, penitentiaries and asylums for the insane, boys in reformatories, defective children, the blind and deaf and dumb, immigrants and all foundlings. This state service would so supervise the health of school children that all our present amateur efforts towards child-welfare would become superfluous. It would take charge of all hospitals, general, surgical, maternity, for venereal diseases, for cancer and

incurable diseases, and, of course, of all sanatoria, for all such institutions would then belong to the state. The service would supervise the noble nursing profession in all its activities. It would investigate all problems coming under public sanitation—adulteration of food, the storing, cleansing and distribution of water, inspection of ventilation, quarantine, prophylactic inoculation, and everything else included under "State Medicine" in the older, more restricted acceptation of that term. It would supervise all specialisms and techniques, including dental surgery, orthodiascopy and the therapeutic use of all forms of energy. Naturally, the compilation of vital statistics would fall under the province of the service. Finally, it would not only organize, direct and reward research, but also organize direct and reward all forms of teaching required in the medical profession; for by the time of which I am speaking, the universities, like the hospitals and laboratories, would have become state institutions. There would not only be no private hospitals, there would be no private schools of the cause and treatment of rheumatoid arthritis and other medicine whatsoever. Research into such large problems as widespread diseases responsible for a large measure of national inefficiency and suffering, could at last become a national affair and be investigated on an adequate scale.

This is neo-socialism, socialism in excelsis, which has absolutely nothing to do with the socialism of the red tie and the levelling down to an h-less vulgarity. Therefore, for this neo-socialism a name is needed; I would suggest *cooperationism:* for we are thinking not of any ideal and, indeed, wholly Utopian conditions where all men are considered equal (which they never were nor can be), but of a social state in which the special attainments of the cooperating few are specifically organized for the benefit of the many. Individualism, often heroic beyond all description, was sufficient for the earlier, ruder, simpler and smaller communities; but cooperation, the organized working for the common good, is the goal we aim at in this newer and truer socialism. Individualism meant rivalry and jealousy, a waste of energy with its consequent detriment to science; cooperationism means a unity of plan and a definiteness of purpose with its corresponding increase in efficiency. The gain from all this to the ordinary, ungrouped member of the community is at once apparent; not only would he command the very highest skill in diagnosis and treatment, but there would be no longer any need for him to subscribe to sickness clubs and similar societies, since he would

belong to a nation which was one vast mutual benefit society. He would, like the Chinaman, pay to be kept well; but if by any mischance he did become ill, he would have, as it were, round the corner all the resources of a world-wide empire to cure him.

One must gratefully acknowledge that a Department of Health has been created in Great Britain, and that in Canada by an Act which passed the House of Commons on April 14, 1919, a similar department under a deputy minister has come into existence. Some of the duties to be undertaken by this new department are: the maintenance of a national laboratory for public health and research work; inspection and medical care of immigrants and seamen and the administration of marine hospitals; the supervision of all matters relating to the health of those employed on railways, boats, ships and all forms of transportation, as well as the health of civil servants and of all government employees.

If one sketches the organization for London and Great Britain, then it could be adopted by any other part of the Empire and modified if necessary to suit the particular local conditions. Naturally, the organization of the R. A. M. C. is the one to be followed as a general model. The headquarters staff would have to reside in London and direct the service not only in London itself but throughout the whole country. The size of London makes it unique in respect of any organization, and it has to be treated as equivalent to a whole district.

After London in order of importance would come the large provincial cities, Edinburgh, Glasgow, Birmingham, Liverpool, etc., each of which would have to be administrated by a staff for itself. In each the hospitals would be so organized as to provide for in-patients, out-patients, laboratory diagnostic work, and all the necessary technical, diagnostic and therapeutic activities. The practitioners of each city would all be organized into the resident hospital service, the out-patient service and the general city service. No one of these would be considered more honorable than any other.

Associated with the great city hospital would be a group of small towns, each with its hospital, and associated with each of these would be a group of rural or cottage hospitals.

There is no question as to the S. M. S. being a costly service. It might, however, prove in actual experience not so costly as at present on paper it seems to be. For, in the first place, in a state which adopted cooperationism the enormous expenses previously needed for the upkeep of the huge navy and the

army would be saved. In the next place, a great many institutions having private endowments from public or private charities would have their funds taken over by the state as trustee, and would therefore cost the state by so much less to administer. Thirdly, the vast sums now given by public and private charities would become part of the taxes for the public health paid by everyone towards the upkeep of the service. Fourthly, the endowments of certain old and large British hospitals and seats of learning would pass over to the custody of the state. From the patient's point of view, the service would be a glorified state insurance against illness, not, of course, as a charity or on the meagre scale of a private mutual benefit society, but on that of the greatest and most enlightened empire in history. Colonel Maurice says the funds could be raised (1) out of general taxation on the budget, (2) by rates and (3) by a special public health assessment applicable to all adults according to their means.

The benefits of a state medical service are evidently twofold; those accruing to the members of the medical profession and those to the public. In the first place, as all properly qualified medical men would become registered in the national service, the quacks and irregular practitioners would soon be exposed and got rid of. Osteopaths would become licensed masseurs and nothing else. "Homeopaths" and "faith-healers" would cease to be, because they would not possess the state license to practise.

In the next place, there would be no struggle for existence, for each man would have a salary sufficient for his needs from the outset, and the prospect of a disability or old age pension, as the case might be.

The soul-destroying competitions, rivalries and jealousies of the old régime would to a large extent disappear. There would, however, be plenty of incentives to the ambitious men to rise in the profession, there would be plenty of research to be undertaken, plenty of rough places to be made plain. No one can say that there are not plenty of incentives to rise in the state professions of the Navy, the Army or the Law; and it need not be any the less so in the State Medical Service.

The advantages to those in need of treatment, are, in the stock phrase, "too numerous to mention." The public health would be preserved as never before; treatment would be prompt and of the very highest quality. Specialists of all sorts would be easily accessible, and all manner of special treatments readily available. There would, on the one hand, be no possibility of overlapping, nor, on the other, could there be whole

districts of many parts of the empire without a medical man, as at present.

In Colonel Maurice's scheme the salaries to officers in the service run from £300 a year ($1,500) to £5,000 ($25.000). Colonel Maurice says that under a state medical service the medical man would be relieved of the expenses of traveling, of instruments, consulting rooms, drugs and dressings. For the highest administrative ranks, he says "the pay would be at least equal to the highest ranks of the civil service." We may take it for certain that the scheme will be a complete failure if, in respect to pay, pensions, prestige, Royal and social recognition, titles and other rewards, this service is in any way inferior to the Civil Service. It must be recognized by the state, and it will soon thereafter be recognized by the public, that it is just as honorable to save a life as it is to blow up an enemy of one's country or sentence a criminal to be hanged.

Under cooperationism the health of the commonwealth is considered a more important affair than any other aspect of the national existence. As has been mentioned, entrance into the S. M. S. would be by the regular final examinations of the state universities, it being the understood thing that every medical graduate was destined for that service. Successful candidates would be graded according to their relative standing, and to some extent allowed the choice of positions, as in the civil service. The pay of all members would not, of course, be equal. In cooperationism there are grades of service, and remunerations vary with height therein and with responsibility. Some men prefer to remain in the lower grades with few or no responsibilities; others, capable of assuming responsibilities, are allowed to do so and are rewarded accordingly. Retirement on pension at certain ages differing with the position attained in the service would, of course, be duly provided for. The medical profession is the one doing the maximum amount of work in the interests of others, and this proposed organizing of it would be the official recognition by the state that these things are so.

In conclusion, let us look at certain objections and criticisms.

As there is nothing new, so there is nothing perfect, under the sun. The following are among the objections that have been raised to the state medical service:

1. It would do away with the patient's right of choice of a physician, surgeon, obstetrician, etc. It is asked: are rich and poor, leaders in society and persons not in society at all, the unco' guid and the declassé all to be treated by the same medi-

cal man or in the same institution? I can do no better than quote Colonel Maurice's answer to this: "It has always been the case that certain surgeons, physicians and obstetricians have earned great reputations, are in great demand and are able to command large fees; and always there have been wealthy persons prepared to pay the fees such highly considered men demand for their services. Some have special faith in one, some in another; and some only ask that some one of great renown shall operate upon them or those dear to them. There is no reason why such a system should not continue with a state medical service. The state will provide efficient attention for every citizen and will appoint to each his medical attendants, and will see to it that each can get the special skill and nursing appropriate to his or her case. Every man will be safe to trust to the organized care offered him, but if he fancy some special surgeon or physician of whom he has heard, there will be no reason why he should not choose (if he cares) to pay a special rate for that man's services. A rich man, then, has appendicitis. He has at hand in his sub-district a surgeon thoroughly competent to operate on him, and he can, if he choose, take a special ward in his district hospital for the rental charged for it, or he can, if he be frugal-minded, use the free wards and go in and be operated on by the surgeon free of all operation fee. But he has heard that some man has a specially great reputation or is fashionable because he has operated on royalty, or he fancies him for some reason or no reason. There is nothing to prevent his demanding the services of that surgeon and paying his fee. The fee will vary with the man just as it does now, twenty-five guineas, fifty guineas, a hundred guineas or more. . . . But the surgeon is the paid servant of the state, paid out of taxation or special medical contribution; he can not, therefore, be allowed to turn aside from his state service for special cases and receive double pay. He must share his fee with the state. As it is important to stimulate men to make themselves fit for the front ranks of the skilful and to stay there, it would not be politic to take all of such special fees. The great surgeon is drawing £3,000 a year from the state. His special fee is fixed at from 100 guineas to 250 guineas. He goes to the rich man, takes 100 guineas fee and gives 50 guineas to the state. So if he does one hundred such special operations in a year, he will make £10,000 a year and more for himself and the state will get back in half fees all his pay and get work from him into the bargain. Nor can such a scheme be considered unfair to doctor or

patient. To the former, ever since he entered the service, the state has assured a competency and given education and opportunity. To the patient, the state, through its carefully trained and supervised medical service, guarantees competent medical attendance at no more cost than the common taxation necessary to secure it. If through whimsicality or for more excusable reason an individual wishes to upset the state arrangement by a special call, it is not unfair that he should pay a special rate for the privilege."

In all probability something like this would happen—the hospitals belonging to a rich and fashionable district would soon be frequented by a rich and fashionable clientele; the others by others. There would be a process of natural selection on the part of patients in respect of individual physicians, institutions, districts; and in a short time, social segregation and sedimentation would have worked out society's own salvation.

So far the objections contemplated apply less to a democratic country like Canada than to a country like England, which still possesses a landed aristocracy and where social distinctions are still numerous and fairly well defined. Naturally, we could hardly expect His Grace the Duke or His Grace the Archbishop to be treated at the same clinic as his coachman or his butler. Certain hospitals would in time become so popular with a certain section of the wealthy or exclusive set that they would virtually correspond to the expensive private hospitals of the old régime.

More real as a factor working for failure is the ingenuity of human nature to wreck the fairest scheme ever put forth by the human brain. The odious system of political patronage, whereby incompetent persons can be appointed to positions intended to be filled by experts, can blast schemes that are brightest. The state medical service by its very nature and aims ought to be the one most remote from the baneful influences to which we are now alluding. The service would be administered, not by lay figureheads, but by medical men and the experts themselves. The appointees would receive their commissions not by favor, caprice or nepotism, but by merit brought out at examination.

There is no Eden without its serpent: but if any organization of human contriving might reasonably be expected to be free from the reptilian blight of political interference and mismanagement, it surely would be that of the State Medical Service.

THE ECONOMIC IMPORTANCE OF THE SCIENTIFIC WORK OF THE GOVERNMENT. III

By Dr. EDWARD B. ROSA

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METALLURGY, CERAMICS, AERONAUTICS, ETC.

MANY other examples of the economic importance of scientific research and standardization could be cited, if time permitted. The metallurgical industries have been greatly developed in recent years through scientific research, and there is now greater activity than ever in this field. The metallurgical division of the Bureau of Standards works in close cooperation with the engineering societies and manufacturers, and is doing work of very great industrial importance. The manufacture of glass, porcelain, tile, and other clay products has been greatly stimulated during the war by the cooperation of scientific laboratories, and vast benefit would be derived by these industries if this cooperation could be continued and even increased. The measurement of temperatures and especially high temperatures is a problem of continually increasing importance in the industries, and many scientific investigations are continually arising in this connection. The intelligent and efficient development of aeronautics depends on the possession of full and reliable information as to the properties of materials, the accurate measurement of the performance of machines, experimental researches in mechanics and aerodynamics, and the most intelligent utilization of existing and newly developed information. Considering the amount of money that is being expended in the development of aeronautics, it would seem that a very considerable amount should go into scientific research. The measurement of color and of illumination and of the optical properties of materials and the development of optical methods and instruments form together a field of investigation of great scientific and economic value. It is impossible even to mention all the subjects of importance in this connection, but enough has been said to show how vast the field and how practical the results that are obtained whenever science is appealed to in answering the problems arising in the industries.

RESEARCH BY LARGE CORPORATIONS

The Standard Oil Company has attained a wonderful reputation for its technical and commercial success in deriving valuable products from petroleum, a result which could never have been reached without extensive scientific research.

The General Electric Company has achieved notable success in the development of electrical instruments and machinery, electric lamps, steam turbines, the applications of electricity to ship propulsion, etc., and a very large part of this success may be credited to its scientific and development work. Its research laboratories have turned out many valuable contributions to science, in addition to the results of direct application in their business. The American Telephone and Telegraph Company, and its subsidiary, the Western Electric Company, have achieved a world-wide reputation for their development of long distance telephony, multiplex telephony and telegraphy and radio telephony, as well as for the development of many of the engineering features of telephone practise of the present day.

These and other great corporations carry on research work on a generous scale and derive great commercial advantage therefrom. But thousands of smaller companies can not do what they do. The smaller companies are, however, rendering the public a service that is very essential, and the public will serve itself by helping them to improve this service. This does not mean that they will have their burdens carried for them by the government, but rather that the government as the agent of the public should participate in research and standardization work (in cooperation with manufacturers' associations and engineering societies) in order that the public may be better served and in order that the public may judge more intelligently of the quality of the product or the service rendered. It is the open door method of doing business as opposed to the method of keeping the government and the public in partial ignorance. The burden of this work when borne by over a hundred million people is very light; the benefits far outweigh the cost. The American Telephone and Telegraph Company's research laboratories employ more research workers in their single field of investigation than the Bureau of Standards does for all its many lines of work for all the industries of the country. The results obtained justify the large expense for research in the telephone field. The splendid results obtained are not due merely to the fact that the work is well managed and is done by a great corporation; but rather to the fact that abundant resources (provided by the public) are made available and an adequate scale of salaries is paid. Government laboratories could do as well if they had an equal or nearly equal chance; but they can not work miracles.

THE ECONOMIC VALUE OF STANDARDIZATION

The American Engineering Standards Committee has recently been formed to promote engineering and industrial standardization. Five engineering societies and three departments of the government were represented initially in its membership. Several additional member societies have just been added and others will be added from time to time. The Committee is already actively at work in selecting sponsor societies for standardization work and approving standards. The government is rendering a valuable service to the industries, and thus to the people, by cooperating actively in this constructive and useful work. Manufacturers have not cooperated with one another in the past in standardizing designs as much as they could have done if there had been some practicable way of cooperating. They have resented government dictation and control, but they welcome government cooperation in constructive work that benefits both them and the public. In many cases the designs and sizes of machines and materials manufactured by different concerns are different because development has been independent. In other cases it is in order to have something upon which to base a claim of superiority. In either case, too many sizes and designs and lack of interchangeability increase the cost to the manufacturer, to the distributor and to the user. Nothing promotes economy and efficiency in the use of raw materials and finished products more than intelligent standardization. It reduces the varieties and sizes of materials that must be supplied by the manufacturer, lessens the stocks that must be carried by the distributor, makes the cost of the finished product less and reduces the trouble and expense to the user in caring for and keeping in repair machinery and equipment of all kinds. The high cost of the services of the plumber have been proverbial for years. Standardization in plumbing fixtures and fittings, and interchangeability of parts could be carried further than it has been. This would greatly reduce the charges for time and material in making repairs as well as in the original installation. The enormous and confusing variety of lighting fixtures, and the bad design of many, are due to utter lack of standardization or cooperation of the manufacturers with one another. Inefficient and dangerous gas appliances have been sold to the public for years, and many are still in use. The manufacturers can not be blamed, for they can not separately engage in expensive research to arrive at correct designs. The only practicable way is for all to cooperate and for the government to take an active part, helping the manufacturers to study these problems of design and standardization intelli-

gently and thoroughly. Manufacturers are glad to cooperate in such work. Since the war particularly, the high cost of labor and material have shown the necessity for economy and increased efficiency, and manufacturers are welcoming the assistance of the government as never before.

The Duty and Opportunity of the Government

Such work is constructive and wealth producing, and yields returns a hundredfold upon the investment. The benefit is almost immediate and not only are there material returns in decreased costs and improved service, but such cooperation between the government and the industries is helpful both to the government and to the industries, and raises the standards of business. It emphasizes good quality and good performance and good service, and reduces misrepresentation and exaggeration in selling. Is it not the duty of the government to cooperate more actively in this constructive way with the industries? No other agency can perform this important function. The government would do only a part of the work, but that part is of great importance. Engineering societies, manufacturers' organizations, and individual manufacturing companies will do their part, and in many cases the greater part. But if the government refuses to do its part on the ground that it would increase taxation, the public will not be satisfied with the reason given when it knows that at the present time out of $50 per capita per annum collected by the government for all purposes, *scarcely more than one cent per capita per annum is expended by the government for this important work, and five cents per year per capita would accomplish wonders.* The matter is of so fundamental importance, and promises results of so great economic and social value, that it is to be hoped that some more adequate effort along this line may be made. It seems impossible that such effort would not succeed at least in part, and even a partial success would more than repay the cost.

The English Journal previously quoted says this of the government's part in scientific research. *"The endowment of research and the financing of scientific investigation are essential in any progressive nation, and if the money is well spent no amount allocated to these branches can be too great at the present stage in our country's history."*

In Great Britain the Engineering Standards Committee is largely financed by the government, while the Department of Scientific and Industrial Research is a government body financed entirely by the government. The American Engi-

neering Standards Committee and the National Research Council (of America) are financed entirely without government aid. This is an additional reason why government research institutions in America should be so well supported that they can do their full duty in cooperation with privately supported scientific and industrial institutions which are doing work in the interest of the public.

Government Laboratories and their Trained Personnel Available for War

The war called for scientific research in connection with the standardization and making of munitions, finding and using substitute materials, locating enemy guns by sound and flash ranging, locating submarines, building and equipping ships and submarines, building and equipping airplanes, dirigibles and balloons, and many other major subjects as well as countless minor ones. This called for well-equipped scientific laboratories and the trained personnel of research workers and assistants. The government laboratories were utilized to the limit of their capacity, and all kinds of makeshift facilities were pressed into service. If preparations had been begun several years before, it is needless to say results would have been obtained sooner and the war appreciably shortened. In view of this experience, and the probability that science and technology will be no less important in the future than in the past, the question naturally arises whether the government is making adequate preparation for scientific research as a part of its program of military preparedness? In time of war the civil branches of the government will be called upon immediately for service, and they will be able to render invaluable service if they are adequately equipped and manned. In the meantime, pending the arrival of the war, which we hope will never come, they will be able to render useful service in civil problems and so be more than self-supporting. This kind of preparation for war, which adds nothing to the military budget if the civil departments are adequately supported, should appeal to all as practicable and desirable.

Summary of the Argument

The federal government having emerged from participation in the world war, finds itself with a large debt and heavy annual charges caused by the war. These together with the current cost of the army and navy amount for the present fiscal year to 92.8 per cent of the total budget. The cost of public works and the necessary administrative cost of the

federal government amounts to 6.2 per cent of the total. There remains one per cent for a large number of governmental activities classed as research, educational and developmental. The question arises whether in the interest of economy and efficiency the one per cent. shall be decreased; or because this work is constructive and of great economic value it should be increased, possibly doubled. The arguments in favor of increasing it may be summarized as follows:

1. The government should be constructive and helpful to the people and to business wherever possible. It should develop the industries, assist in improving commercial and industrial methods, and furnish technical information to manufacturers and others, as well as develop agriculture and the public domain. By rendering such service the government tends to establish good relations with business, to elevate business methods, to increase efficiency and to educate in many ways large sections of the public. The many services thus rendered cost very little in the aggregate as compared with the total expense of the government, but they are of great practical value and are appreciated by the people. *One per cent of the total expenses of the government spent in this constructive way seems a very small proportion in view of the wide range and the economic value of such work.*

2. But a part of this one per cent is incurred in behalf of the government itself, to enable the government to purchase its supplies intelligently and to do business in a business-like way. Without this research and testing work the government would waste more in buying than it would save by eliminating the research and testing. Making purchases without full technical information is embarrassing to public officials and unsatisfactory to business; whereas by always using intelligently drawn specifications and making adequate tests, the government can save money, elevate its own service and improve business methods. Much but not enough of this kind of work is now done. It is the duty of the government to set a good example before the business world of efficient and intelligent methods and fair dealing; neither accepting goods below the specified quality nor demanding more than is specified. *The government would spend less for its purchases if it spent more in standardizing the products purchased and in testing deliveries systematically.*

3. But apart from the service the government can render its citizens, and the benefit to the state resulting from scientific, educational, and developmental work, and apart from the benefit to the government of having the results of such work in constructing buildings and other public works, and carry-

ing on its business, this kind of work develops wealth, and the increased wealth can be taxed, and hence there is a third reason for increasing such work. The war has made it necessary to raise many times the revenue formerly required, and the taxation is now an important issue. Economizing in the use of raw materials, using cheaper materials, reducing waste, developing the public domain, increasing manufacturing efficiency, reducing distribution costs, all tend to create wealth and to make it easier for the government to raise the needed revenue. Therefore, if there were no other reason, this consideration should appeal to legislators and business men alike; *namely, that research and development work by the government develop wealth, and the burden of taxation is thereby lightened.*

4. But there is another powerful economic reason for increasing the productive developmental work of the government. The rising cost of living not only leads to hardship and distress, but to industrial unrest, strikes, disorders and great economic losses to the nation. In order to check rising prices, and if possible bring down prices, it will be necessary to increase production. To do this it is necessary to reduce waste and increase efficiency. This requires greater intelligence and fuller knowledge, and calls for education, the results of scientific investigation and of intelligent and extensive industrial research. The government could not and should not do it all. But neither should it refuse to do its part, and its part often is to take the lead in a constructive and statesmanlike way. It is stupid and blind to think that because taxes are heavy we can not afford to do things intelligently. If a farmer's barn burns down, he would not sell half his supply of seed and fertilizer to buy lumber, and then plant only half a crop. He would, if necessary, borrow money to buy more seed and plant a larger crop than usual, in order to increase his income and pay for the new barn more easily. *Intelligent research by the government, in cooperation with the industries, is like seed and fertilizer to a farmer. It stimulates production and increases wealth, and pays for itself many fold. It is as productive and profitable in peace as in war.*

5. Finally, if the reasons already adduced are not sufficient, there remains the military reason. The development of our intellectual, moral and material resources is the best preparation for war. Food and manufacturing facilities, and adequate supplies of raw materials and transportation systems and scientific attainments and the equipment and trained personnel available for military research, these together with an

intelligent citizenry and a just cause are the best preparation for war. A standing army and fleets of battleships are necessary but not a sufficient preparation, even if the army is armed to the teeth and the battleships are the heaviest or the swiftest in the world. The Great War demonstrated that modern wars are not of armies but of peoples, and their resources and their intellectual and industrial resourcefulness are more important than the initial equipment of armies and fleets. Therefore, a government that pays much attention to education and research and industrial developmental work is making the best preparation for possible wars of the future. *This fortunately produces good results if war never comes. By increasing the power and prestige of the nation, such preparation tends to prevent war, and so pays for itself twice over.*

Conclusion

Probably every one will grant the principle that a government should do something to educate the people, and to develop the industries and the natural resources of the country. It is only a question of the scope and extent of such work. The government has already done much, but in comparison with the needs and the opportunity it is inadequate. Cooperation of all the people in developing themselves and improving their condition and securing protection against the selfish and unfair efforts of individuals or corporations or groups, is more necessary in the modern state than formerly. And when the state contains a hundred million people and covers a continent, effective cooperation in many cases can be attained only by government assistance and leadership. Friendly governmental cooperation and constructive assistance in the industries are more welcome than regulation and repression. We must have the latter in some cases, and that is an additional reason why we should have a generous measure of the former. How far we should go experience alone can determine. But we should have the courage to face the facts, to analyze them correctly and, both in the government and in the nation, *to do as well as we know how*. We should strive for a higher and truer efficiency, for efficiency in the government, efficiency in labor, efficiency in business; and the government should not fail to do its part, which in many cases is to take the lead. If the government will cooperate with the industries in peace as earnestly and effectively as the industries cooperated with the government in war, it would be of vast benefit to the public, which pays all the costs.

DEMOCRACY'S OPPORTUNITY[1]

By Dr. STEWART PATON

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THE present moment is an interesting as well as dramatic one in the history of civilization. The recent military victory of democracy over autocracy marks progress in formulating a reply to the question to what extent man is justified in having classed himself as homo sapiens. Is he really "the wise man"? Will it be easier under a democratic than it was under the autocratic régime to substantiate his claim to the title? Does his behavior since the war presage that reason henceforth will count for more than it ever has done in the control of human affairs? Will democracy be equal to its present opportunity of assisting in the study of man with the object of finding out how thought may be liberated from the domineering control of instinct, custom and precedent, thus replacing eventually a rudimentary rationality by fully developed reason. In view of what is going on in the world, could any more important service be rendered to a government than is expressed in the purpose of this society to study man in order to find out first, what the forces are in his personality that would both quicken the development of his reasoning power and second assist in the gradual elimination from the human race of those traits that make it easy for man to-day to wish intemperately while limiting his capacity to reason connectedly. These are matters of transcendant importance.

Since eugenics calls for the solution of problems of vital importance to the race this society can not afford to be even indirectly associated with any propaganda or uplift that is purely emotionally directed and is an indication merely of the wandering of desire. The organizers of this society very wisely emphasized the word research, and thereby disclaimed all connection with the enthusiasts who rush into the field of eugenics armed only with good intention. The campaign upon which so many important issues depend should be very carefully planned. There are, however, unusual difficulties at present in trying to effect a rational organization for any purpose. One of the first steps is to be sure we have correctly visualized our problem.

[1] Address of the President of the Eugenics Association.

An unfortunate effect of the war has been to give us a false perspective: man's actual place in nature and the importance of events in his history once again have been misjudged. We need to be continually reminded of the fact that, if the history of the earth's crust is divided into twenty-four hours, primitive man first appeared on the scene during the last quarter of an hour, while civilized man—this same man who boasts of possessing huge armies and enormous guns—has existed for about twelve seconds!

Once the perspective is corrected, there is more chance that a few of the various problems perplexing us to-day will be correctly appraised with the result that we shall take many of our conventionalized opinions less seriously and shall be in a better frame of mind to consider, with all its consequences, whether man is becoming more or less rational. Probably occasional reflection upon the real, not imaginary, place occupied by man in nature would have a salutary restraining effect upon those ardent expositors of half-baked schemes for reorganizing government or improving the race who, unable to distinguish between the products of wishful- and reality-thinking, have derived their notions as to what man's capacity and needs are from the present very limited supply of facts. Man, while taking his opinions about himself very seriously, seems to ignore almost completely his defective self knowledge and except under pressure steadily refuses to observe the precautions necessary for making reason a more potent influence in the control of behavior. In as much as we are inclined to overestimate man's capacity for rational thought, we should remember how often human affairs at present are discussed in a manner that suggests the irritability and censorious manner of a psychoneurotic personality. A peculiar emotional disposition unfavorable for the development of reason increases the difficulty in reaching a just decision in regard to all questions now before the world. For this reason eugenics has a larger task than that comprised merely in the acquisition of facts. It depends for success upon the preparation the human mind has had to accept the truth whenever it is presented. As preliminary to this success, it is essential that attention should be given to the various influences now holding reason in check, and an effort should be made to remove these and leave man in a better position than he is in to-day to decide great issues intelligently. This will be a difficult task requiring both patience and intelligence.

The great question we are facing in the world is not the adjustment of boundaries, nor the settlement of European

affairs on a peaceful basis, but the real issue is whether man is capable of reacting favorably to the appeal of reason. Historians say we are passing through a crisis in western civilization, statesmen declare the principles of liberty and justice are jeopardized and that the tragedy predicted by the prophets of the eighteenth century has been enacted with an indefinite prolongation of the tragic epilogue. The significance of all this trouble expressed in simplest terms, and avoiding all show of rhetoric, is that man has become unmanageable because he is not understood. In view of the present confusion of minds throughout the entire world, and the immediate dangers arising from egotism and frenzied outbursts of pride and ambition, it is obvious that any society organized as is the Eugenics Research Association for the express purpose of finding out what constitute the desirable and undesirable qualities in the human personality and to do whatever is possible to assist in cultivating the former and eliminating the latter is actually engaged in laying the only foundation upon which democracy can ever hope to build securely.

The functions collectively designated as reason represent a final stage in man's long evolutionary history. Rationality is a collective term for a group of functions only recently acquired. Of course, it is obvious to any intelligent person that we can not understand either the nature of these functions or the conditions favorable to their development without a definite and exact knowledge of man.

Autocracy failed largely because it did not possess this information and asked to have the world made safe for a system arbitrarily selected for controlling human behavior. Germany's effort to control the affairs of the world failed because little attention had been paid to the study of man as he is.

The success of democracy depends on the cultivation of quite a different mental attitude towards the great human problem. We can not afford to imitate the blustering boastful methods of autocracy, nor to ask to have the world made safe for any particular system of organized control, until we know what the forces are that determine mental attitudes, extend the sphere of reason, and what methods may be used to minimize or eliminate the influences that distort the mind and give rise to a series of irrationally constituted opinions and a mental vision blurred by seeing the world through false refracting media.

The degree of intelligent interest and amount of support given to any well-organized movement to encourage the study of man as he is are indications of whether democracy is prepar-

ing to make good use of its present unique opportunity of placing reason in control in the direction of human affairs.

Democracy can not endure unless it succeeds in making man "the true study of man." In order to attain ultimate success there must be a clear appreciation of the nature of the methods to be applied in securing the desired information, and these methods will now be briefly described. Two distinct lines of attack are open to us in seeking for information relating to the laws governing human behavior. In the first place, there is the analytical method, also described as the elementary point-of-view, characterized by careful painstaking study of the different organs and structures composing the body. In marked contrast to this method of procedure there is the synthetic method, the study of the machine as a whole, which unfortunately has not been generally recognized by scientists as being of equal importance to the former procedure. There can not be too much analytical research, but, as George Sarton has reminded us, this must always be balanced by a corresponding amount of coordinating work. The detailed information supplied in regard to the parts and different mechanisms of the human machine must be correlated with what we know about its behavior as a living organism, adjusting to meet the demands made in the particular environment in which the individual lives. The failure to appreciate the value of the information derived from the study of human beings considered as living, functioning, biologic organisms has had not only unfortunate, but often tragic results. This oversight has resulted in the attention of physicians and psychologists being devoted almost exclusively to the use of analytical methods and has given little opportunity to demonstrate what results can be accomplished in explaining the phenomenon of behavior by the combined use of the two methods. At present, the methods used in training physicians suggests the mental attitude of those who work only in repair shops in which the human machine is taken apart and the different organs examined, but where little provision exists for following the machine on the road, observing its behavior and taking note of the immediate effect of the strain and stress of living as expressed in the complex functions of the human personality. The disadvantages of placing too much faith in the efficacy of analytical methods are easily recognized by those who take an intelligent practical interest in the subject of eugenics. Every investigator in this field should be familiar in a general way with the technic of examining analytically the different organs as practised by

expert clinicians, but in addition there should also be plenty of opportunity for becoming acquainted with the difficult art of studying the synthesis expressed in the personality.

Not only is it necessary that the investigator in eugenics should have some practical experience in the difficult technic of examining human beings, but it is equally important that he approach the problem from a broad biological point of view. He has to consider in the first place the machinery which is the product of evolution and then equally important is the observation of variations in behavior as the environment changes. We are altogether too much inclined when discussing the possibility of the inheritance of definite functions and traits to treat these as if they were specific and sharply defined qualities; and this is not the case: Another mistake often made is the tendency to regard the transmission of traits of temperament and character as the result of the functional activity only of the brain and nervous system. These so-called psychological phenomena should be discussed as biological reactions of the entire organism. In other words, we should never forget that the functions of the brain and nervous system are being continually modified by the action of other organs. When once we grasp the full significance of this principle we shall be less inclined to stress the importance of intelligence tests, or in any way to convey the impression that the consideration of the functions of any one organ, or groups of organs, may be correctly gauged without taking into account the modification produced in these reactions by a great many different factors that are too frequently overlooked or ignored.

Many of the difficulties that man has been obliged to overcome before discovering a successful method for analyzing his personality are of his own making. Progress in this direction has been unnecessarily slow on account of his tendency to create artificial distinctions in studying physical and mental processes. We should plainly recognize the fact that the investigator who approaches the study of man from the specialist's standpoint without being thoroughly drilled, not only in general biological but also in clinical principles, so that he recognizes the integrity and unity of living organisms, is bound to make serious mistakes in interpreting the phenomena of behavior.

Man's intellectual conceits and personal vanity have also told heavily against him in the efforts to know himself. He still discusses his higher intellectual functions as if these had little connection with the lower forms of adjustment, represented by adaptations at the physical level or by reactions of

lower animals. Even if this belief is seldom expressed, the mental attitude persists that is responsible for the assumption that persons who have not had practice in the clinic in the study of the functions of different organs are, without further preparation, equal to the task of analyzing the subjective phenomena represented in the personality. On the other hand, the assumption is also equally erroneous that investigators trained solely in the study of the bodily functions are equipped to undertake the analysis of the mental reactions.

The science of eugenics, as we all know, is still in its infancy, and its development should be directed along rational lines. A false step, the result of an enthusiasm often born of the best intentions, but not held strictly in check by reason, may have unfortunate results and give some justification to the reproach that this movement having as its object the improvement of racial prospects is a fad. The possible good that may eventually be accomplished by the selective breeding of human beings is a subject making such a striking appeal to the active imagination that the preliminary preparation necessary for the patient search for the essential facts may be forgotten or completely ignored.

A moment's reflection should be sufficient to convince any one of us that we can not go very far in the study of eugenics without the assistance of a body of investigators specially trained in the difficult act of studying the personality. The data supplied in personality records should be as severely criticized as are the histories of dogs or horses used for breeding purposes. Our common-sense tells us that the best judge of the good and bad qualities of these animals is the person who has had practical experience in studying canine or equine behavior coupled with some knowledge of the general anatomy and physiology of *these animals*. Exactly the same principle should be applied to the study of man. We must know something about human anatomy, physiology and psychology, and this information must be corrected and supplemented by deductions based upon the observation of the daily life of these beings. There are very few investigators trained in the art of observing human behavior. A good many people, speaking in relative terms, understand parts of the machinery and judge its performance from the angle of the physiologist or that of the psychologist interested in some particular aspect of adjustment, but there are relatively very few possessing this information who are able to tell us much about the reactions of the machine as a whole to the conditions actually met with in life. A

personality can not be judged correctly from the standpoint of either physiologist or psychologist. The specialist's approach to the problem should be broadened out so as to include the information relating to the daily life of an individual, giving some indication of how obstacles are met, overcome, or avoided.

Eugenics is confronted by the same difficulty in securing thoroughly trained observers that has been such a serious obstacle in the path of modern psychiatry. Relatively little interest is taken in the medical schools in disorders of behavior, and practically little attention is paid to training students in the complicated art of analyzing character. This indifference of the general as well as medical public to the need of making adequate provision for investigating the disorders of conduct usually described as nervous and mental diseases has had most disastrous consequences.

The high rate of incidence of specific nervous and mental disorders as well as the increasing symptoms of nervousness has become a menace to our civilization. The point to which we wish to direct attention especially at present is that the indifference of the medical profession, as well as of the public, to the study of human behavior has not only been largely responsible for the increase in these diseases, but it has created a serious difficulty in developing the science of eugenics. The fact that we know so very little about the laws governing human behavior and the organization of the personality has led, on the one side, to conditions peculiarly favorable for the increase of nervous and mental maladjustments and, on the other hand, has deprived us of the knowledge necessary for carrying on an effective campaign to eliminate the unfit and to conserve the qualities essential for human progress.

The following summary of the replies to the questionaire sent by Mr. H. H. Laughlin to the deans of medical schools in the country will give some indication of the little attention paid to the study of eugenics.

I.	No special course given and no interest exhibited in replying to questionnaire	14
II.	No special course, but subject treated in work of various departments	11
III.	No special institution, but hope to organize courses when means are available	1
IV.	No courses, but suggestions welcomed	3
V.	Same as II, but expresses marked interest	5
VI.	Same as II, but also is taught in connection with sociology	2
VII.	No special courses given. Eugenics referred to in connection with one of following subjects—surgery, pathology, embryology, anatomy, zoology	12

VIII. Express regret that no instruction is given 1
IX. Referred for information to other members of the faculty, from whom no answer was received 3
X. School discontinued—Total 53

The work of gathering together a body of well-trained investigators would be aided materially by establishing scholarships in our medical schools for those intending to pursue the study of eugenics. For some time we should not attempt to do more than to carry on a campaign with the object of eliminating the unfit. In order to determine what the undesirable qualities are, it is necessary that those conducting the examinations should be capable of determining to what extent the environment has become a potent factor in changing the personality. In order to do this an examiner should be thoroughly conversant with methods used by the modern psychiatrist in the examination of patients. It is very often the case that undesirable qualities supposed to be transmitted directly by inheritance prove upon examination to be merely the results of repressions in members of a family who have tried to adjust themselves to an environment unsuited to their biological requirements. A change in the surroundings may lead to astonishing results and the supposedly inherited biological tendencies are quickly replaced by more successful forms of adjustment. We do not refer, of course, to the cases of mental defects due to organic causes and which are evidently a direct product of inheritance. We should not make the mistake, however, of entrusting the diagnosis of mental defectiveness to those whose limit of experience in the examination of human beings makes it necessary for them to draw sharp artificial lines of distinction between physical and mental reactions.

A great deal of work is yet to be accomplished in laying the foundations of the science of eugenics before positive direct recommendations for improving the racial prospects are made to the public; except urging the use of selective methods in breeding to eliminate the unfit. Careful consideration should be given to the problem of training investigators in the very difficult part of studying the personality. The analysis of temperament and character can not be undertaken successfully by amateurs. Something could be done to improve the methods used in the study of personalities in relation to the problem of eugenics by establishing fellowships in the medical schools for investigators intending to enter this special field of research. A good deal may also be accomplished in this same direction by improving the facilities for making personality studies that are

present in the psychiatric clinics. The assistants who are to direct the work of analyzing human predispositions and the special traits of character and intelligence will be drawn chiefly from those having had experience in the work of these clinics. While we are discussing the foundations upon which the science of eugenics should be established, we should not omit a reference to the scant provision now made for the study of the brain and nervous system. We are accustomed to refer to normal and abnormal conditions in the structure and functions of these organs as if exact standards of comparison had already been established; and this is not the case. Practically little is known about the great mechanism of adjustment, and it is astounding how indifferent man seems to be in regard to his most recently acquired and valued possession, his new brain. Adequate provision should be made for studying the nervous system as this field of investigation has important connection with the science of eugenics.

The crisis confronting us to-day is a real one, and many people are gradually becoming conscious of the significance of the problem upon which current events are forcing a decision. Behind discussion about social readjustments, rearrangement of international boundaries, and a League of Nations, all of which are practically minor issues, stands the open question whether man is entitled to be designated as "homo sapiens." Do the events through which we are passing mark the beginning or end of the period of rational thought in the evolution of man. Is the triumph of democracy the beginning of a decline to the dead level of mediocrity? We have accustomed ourselves to rely upon wishful-thinking for answer to these questions. Probably if we decide to make the effort, an intelligent reply can be formulated. If democracy assists in making man the true study of man, the chances are that intelligence will become a much more dominant factor in the control of human behavior while mankind will be in a better position both to judge what the racial prospects are and to accept and apply the teachings of eugenics.

THE METHOD OF PROCEDURE IN THE ANALYSIS OF HEREDITY

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WHATEVER the conception we may have of the essential nature of the activities of living things, it must be agreed that as time goes on more and more of them can be pictured in terms of demonstrable mechanical models. I shall leave to others the questions: Why does the biologist get any satisfaction out of such constructions and why does he not rather busy himself with the determination of absolute values?

The first step toward a satisfactory basis for the understanding of the nature of the transmission of hereditary qualities was the proof that organisms as we know them are never derived from non-living things. They are always separated parts of a parental organism something like themselves. This simple proposition was not demonstrated until the last century. From the earliest times it was commonly believed that certain animals at least can be generated from non-living material by the action of external agents. If such a generation is possible it seriously affects our notions regarding the transmission of hereditary qualities. As far as we now know every organism starts as part of a preexisting organism. Our question then is the manner in which this part of the parental body carries the qualities of the future adult individual.

That the qualities of the separated part or germ cell are really of great importance in the development of the new individual, as compared with environmental forces, may be readily demonstrated by placing a fish egg and a frog's egg side by side in a dish of water. The surroundings are the same for both and yet one develops into a fish and the other into a frog. No environmental differences can produce effects at all comparable with these. The relation of these biological facts to certain sociological theories is obvious. The primary differences between human beings as between other organisms are due to hereditary factors and not to environmental factors.

Some have claimed that one egg develops into a fish because it has a non-material force or entelechy which wants it to develop into a fish while the other egg has an entelechy which wants to it develop into a frog. If it were impossible to

make out any units of a lower order than the eggs, if they were the ultimate particles with no visible differences between them, in despair of any other explanation one might postulate that differences in their activities are due to such non-material forces. This is no more than the physicist does with his ultimate particles, though he does not often admit it. On the other hand, more physicists than biologists are anxious to prove that the smallest known particles of organisms have souls.

However, since the egg is not an ultimate particle and it is possible to make out something of the structure and activities of its various parts, the biologist tries to picture to himself the way in which these parts are related to the adult characteristics. He tries to determine how they would act if they were large enough to be handled.

Preformation and Epigenesis

From the time of the earliest philosophers some have denied the problem of individual development by claiming that the egg contains the parts of the adult in miniature and that development is merely an enlargement of these parts. On the other hand, some have denied the presence of structure within the egg and have claimed that development starts with no structure and gradually works toward the complexity of the adult. It will not be worth while to follow here the early history of this controversy between the preformationists or evolutionists, as they were called, and the opposing school of the epigeneticists. It may suffice to say that opinion alternated from one extreme to the other. In the seventeenth century, when the first compound microscopes were used to examine eggs and spermatozoa, the observers were so convinced that the human body was present in miniature that they promptly found it there and published their findings in elaborate drawings of the little mannikin with its limbs nicely folded up like the petals in a flower bud. Those of us who have had to do with students in biological laboratories recognize that people have not changed in this regard during the centuries. It is still very easy to see what you are looking for and still very hard to see things that do not fit into your preconceived notion.

With the construction of better microscopes it was soon made evident that the little mannikins do not exist and there was an early swing of opinion to the opposite extreme. Practically all biologists became epigeneticists, claiming that the egg

is a homogeneous protoplasm in which the adult structures are gradually developed.

Since the middle of the last century, however, there has been a gradual return from this extreme position. Improvement in microscope lenses has made possible a rapid advance in the knowledge of the structure of organisms. It has been shown that organisms are made up of smaller units, the cells, that the ovum and spermatozoon are such units and that all the numerous cells of the adult body are derived from the subdivision of a single cell, the fertilized ovum. Furthermore, it was shown that there is a complicated but very definite mechanism within all cells. Experimental work has demonstrated a specific relation between this mechanism within the egg and the adult structure. The general trend, therefore, is toward a modified preformation. The parts of the adult are not entirely unrepresented in the egg, as in the view of the extreme epigeneticists, nor are they represented by exact miniatures, as in the view of the extreme preformationists or evolutionists. Instead there is a recognition of a definite, specific relation between certain structures and activities in the egg and certain other structures and activities in the adult.

Nucleus and Cytoplasm

The first step in the analysis is the recognition of the difference in function between the cytoplasm and the nucleus of the egg. Within the egg as in every cell two portions can be recognized, a central body called the nucleus surrounded by the remaining substance called the cytoplasm. During the last fifty years a large amount of evidence has been collected which proves that the nucleus and cytoplasm have different functions not only in the ordinary life of the cell, but also in their relations to the transmission of hereditary qualities.

Histological studies have shown that the visible differences in the different tissues of an organism are almost wholly if not wholly in their cytoplasms. The essential differences that we make out between the different cells of the body have to do with cytoplasmic structures. Thus the muscle fibrils, the nerve fibers, the pigment granules and similar modifications in the tissues are all cytoplasmic. There is reason to believe, however, that the nucleus has some causal connection with their appearance.

It has been demonstrated that while both nucleus and cytoplasm must be present in order that development may

occur, they are by no means of equal value in the process. In certain eggs if the nucleus is left undisturbed the greater part of the cytoplasm may be removed without affecting the development of a complete normal individual, and it does not matter what part is so removed. Thus while the nucleus alone can not develop, a small amount of cytoplasm from any location is sufficient to cause it to do so. On the other hand, when the cytoplasm remains intact not only the removal of a part of the nucleus, but even a disarrangement of its materials is sufficient to prevent the development of a normal individual.

Another point in the evidence is the fact that, while on the whole the female and male parents contribute equally toward the qualities of the child, the cytoplasmic contribution of the spermatozoon is negligible in amount. On the other hand, the amount of nuclear material furnished by egg and spermatozoon is essentially equal in amount and, as we shall see, this similarity applies to the details of nuclear structure. Furthermore, the nucleus and not the cytoplasm contains a mechanism in agreement with the facts of experimental breeding.

THE CHROMOSOMES

It is in the nucleus then that we are bound to seek this further mechanism of heredity. Our evidence for such a conclusion has been accumulating very rapidly during recent years, and it is not possible to do more than give some of the striking points.

A detailed microscopical study has shown that there is within the nucleus a material, called chromatin because of its affinity for certain dyes, which behaves in a remarkable manner during each cell division. This material is present in the period between cell divisions in the form of granules. Preceding a cell division, these granules arrange themselves in a row or rows, producing a thread or threads of granules which soon break up into definite segments or chromosomes. These chromosomes are perfectly definite bodies, always the same in number in any species of animal, always breaking up into their constituent granules between cell divisions and always being built up again at every cell division from the egg to the adult. A beautiful structure somewhat resembling the diagrams of a magnetic field is then developed, with two poles, the centrosomes, and with radiations extending in all directions from them. The rays passing from one pole to the other constitute what is known as the spindle. The chromosomes

arrange themselves in a transverse plane at the center of this spindle, each one splits longitudinally, and the two halves travel to opposite poles. The cell then constricts at its equator and two daughter cells are produced each containing a longitudinal half of each of the chromosomes. The whole elaborate mechanism has this one important function of bringing about the exact distribution of chromatin material, so that each daughter cell gets not only the same total amount as the other, but also exactly the same amount of each part of each chromosome. By the repetition of this process every cell in the adult body finally has exactly the same chromosomal complement as every other cell.

It follows from this fact that, on the chromosomal hypothesis, every cell contains a complete set of developmental determiners. Then, why do some cells form muscles, others nerves, still others connective tissue and so on? Weismann's theory involved the assumption that the cell divisions were actually qualitative and that the different cells of the body obtain different complements of chromatin. As stated there is no observational basis for such a conclusion. We are therefore forced to the hypothesis that each cell has all of the materials and the question of why it uses some and not others remains to be solved by other means. The discussion of this problem, however, can not be undertaken here.

There is an interesting modification of this process of equal distribution of chromosomes, during the last two divisions of the germ-cells, those immediately preceding the time when they are ready for fertilization. During the early divisions of the germ cells there is no essential difference between them and other cells, but at one of the last two divisions instead of the ordinary procedure of a longitudinal splitting of each of the chromosomes which would insure the original number in each of the daughter cells, there is no splitting at all. Two whole chromosomes come to lie side by side in the equator of the spindle and each of the daughter or mature germ cells gets a half of the total number. There is thus a reduction to one half of the original number of chromosomes. This takes place in both the male and the female germ cells. For a reason to be mentioned presently, it is customary to speak of this reduced number as n and of the number in the division of ordinary cells as $2n$. It is obvious since spermatozoon and mature ovum each contain n chromosomes that when they unite in fertilization the $2n$ number is restored.

There are a number of other interesting points in connection with this reduction in the number of chromosomes. It

has been shown that a mature unfertilized egg may be caused to start development in other ways than by union with a spermatozoon. The method is not important, since the same result may be brought about by a great many different kinds of agents, as chemical change in the medium, osmotic change, rapid change in temperature, pricking with a needle or even by shaking. The cells of individuals developed in this way have only the *n* set of chromosomes from the ovum, yet they produce complete individuals. Likewise, a small piece of the cytoplasm of the egg without any nucleus may be entered by a spermatozoon, and the nucleus of the resulting fusion contains only the *n* chromosomes of the male. Yet a whole individual results again. It is clear, therefore, that if the chromosomes contain the essential factors in the development of the characters of the individual, the egg contains a complete set of such factors and the spermatozoon contains another complete set. The fertilized egg and all of the cells of the body derived from it must therefore contain a double set.

This is in agreement with the facts obtained by experimental breeding as first made out by Mendel in 1866. Since its rediscovery in 1900 the principle involved in the so-called Mendelian inheritance has been shown to be a general one. A great many hundreds of characters in both animals and plants have been shown to follow it.

The essential point in these phenomena, as pointed out by Mendel before there was any knowledge of a chromosomal mechanism, is that the body of an organism contains a double set of factors, one or more pairs for each of its characters. Any character then is dependent upon the presence of at least two factors, one derived from the male and the other from the female, and these two factors must separate again when the sex cells are produced. Each sex cell then can have only one member of the original pair. Of course, this fact can only be demonstrated when the factor coming from the male is different from that coming from the female, as in hybridization. If in such a case we call the factor coming from one parent *A* and that from the other parent *a*, then the resulting individual will have the constitution *Aa*. When it produces sex cells half of them must carry *A* alone and the other half *a* alone in order to get the proportions obtained in experimental breeding which are one fourth with *AA*, one half with *Aa* and one fourth with *aa*. As Mendel observed, the *A* and the *a* show no contamination as a result of their intimate association within the same body. They are as pure as they were in the original parents.

Mendel showed further that in case there is present in the

same mating another pair of characters due to another pair of factors as *B* and *b*, their distribution is independent of the distribution of *A* and *a*. In the second hybrid generation there is thus a combination of characters which is the one to be expected on the view of independent assortment of the two pairs of factors.

It happens that the behavior of the chromosomes is such as to furnish an ideal mechanism for this distribution of factors. If we place the hypothetical factors for the Mendelian characters in the chromosomes of our model they are distributed in exactly the proper way to give rise to the numerical proportions of Mendel's law.

Differences in the factors contained do not, however, as a rule cause visible differences in the chromosomes which carry them. There is only a single demonstrated case of such a difference and that is in the inheritance of sex. This case is therefore of the greatest interest. In order to make the explanation as simple as possible, I shall take only one of the kinds of differences that have been made out. In a great many animals there is an exception to the rule that $2n$ chromosomes are present in the cells of the body. Instead there are $2n-1$ chromosomes in the cells of the males, while the females have the ordinary number $2n$. When mature eggs are being produced there is the ordinary reduction in the number of chromosomes to one half and all obtain n chromosomes. In the spermatozoa there can not be such an equality because $2n-1$ is an odd number. Accordingly, when the chromosomes pair off in preparation for the maturation divisions, one is left without a mate. One of the daughter cells obtains n chromosomes and the other only $n-1$. Accordingly, half of the spermatozoa are of one kind and half of the other. It follows that since all eggs are alike in having n chromosomes the result of random or non-selective mating gives half of the individuals with $2n$ chromosomes, or the number in the female body cells, and half with $2n-1$ the number in the male body cells.

Another result follows from this consideration. If the factors for other characters than sex are located in these chromosomes they should be distributed according to a scheme differing from that of other characters. This follows from the fact that in the case of such characters half of the spermatozoa should lack entirely any factor for them. Numerous such sex-linked characters are known.

If the chromosomal hypothesis is correct, it follows further that the number of independently heritable characters as far as random distribution is concerned should be limited to the

number of pairs of chromosomes in the species in question. If the factors for two characters are located in the same chromosome they should go together or be linked according to the technical expression. Such linkage has been demonstrated frequently. Furthermore, there is no known case in which there are more independent groups of linked characters than there are pairs of chromosomes. The form in which the heredity of the greatest number of characters has been worked out is the fruit fly *Drosophila* with over 200 to its credit. There are only four pairs of chromosomes and correspondingly the characters are linked in inheritance in four groups. Furthermore, one of the four pairs of chromosomes is very small and correspondingly one of the linked groups of characters is much smaller than the others.

This striking mass of evidence from normal inheritance is confirmed by the experiments with abnormal distribution of chromosomes. The two cases I shall choose in illustration approach the problem from opposite sides.

Boveri produced an abnormal distribution of the chromosomes during the first cleavage of the egg by inducing two spermatozoa to enter the egg at once. He then separated the daughter cells. This was in the sea-urchin egg, a form in which under normal conditions separated cells produce complete individuals. Only a certain percentage of these daughter cells had full sets of chromosomes. The same percentage developed into complete individuals.

Bridges attacked the problem from the other side. In some of his fruit-fly material the inheritance of the characters did not follow the ordinary Mendelian formula. He figured out the kind of chromosomal abnormality that would yield such a result. He decided that the breeding data would follow if, in the maturation of the egg cell, the members of the pair of chromosomes involved did not separate as in normal reduction, but went to the same pole, leaving one of the daughter cells with both members of the pair and the other without any. An examination of these cells made after the formulation of this explanation showed that such an abnormal separation had actually occurred.

These experiments with irregular distribution clinch the argument that the chromosomes are the bearers of factors having to do with the appearance of characters.

THE CHROMOMERES

Within the last few years an extension of our knowledge has shown that the chromosomes can not be considered as the

elementary units in the transmission of hereditary qualities. An analysis of the differences in value between different parts of individual chromosomes is therefore being made.

The possibility of such an analysis was already indicated by the microscopical observations previously mentioned, which showed that the chromosomes are themselves made up of rows of granules. These individual granules are known as chromomeres. It will be recalled that when the chromosomes are formed during cell division each one is made up by the coming together of the granules present in the resting stage of the cell. A large number of cytological observations have made it seem probable that when a chromosome breaks up into its constituent granules or chromomeres at the end of a cell division, these granules do not mix up with others in the nucleus, but occupy a definite region in it. This is made out especially well in certain lobed nuclei in which the separate regions belonging to the individual chromosomes can be definitely mapped out. It is probable therefore that the same granules form homologous chromosomes in succeeding cell generations.

It follows also from the nature of the division of a chromosome that when it splits longitudinally into two equal parts, each granule or chromomere is also split into two equal parts and, therefore, each daughter cell obtains not only a half of each of the chromosomes, but also a half of each of the constituent granules. Each cell of the completed body, therefore, has its equal share of each of the minute chromatin granules present in the egg.

Supposing each granule or chromomere to represent a different kind of material, each cell of the organism has a complete set of materials. All the cells are then qualitatively alike in this respect. The quantitative relations are restored between succeeding cell divisions by growth, as each chromomere is able to build up new material like itself.

It is probable that here in the chromomeres are elements in the mechanism of heredity of a lower order than the chromosomes. If the chromomeres of a chromosome always stick together or if the linkage of characters within a group is never broken there is no way of testing such a hypothesis. Fortunately we have evidence from both sides of such a breaking of linkage.

From the side of experimental breeding, evidence has accumulated that while, according to the hypothesis that the chromosomes are indivisible units, linked characters should stick together, they do not always do so. This breaking of the linkage was subjected to careful study, particularly in the

fruit fly, *Drosophila*, and it was shown that the breaking never takes place in the formation of the spermatozoa but only in the formation of the eggs. Furthermore, taking a linked group such as that which is found in the same chromosome as the sex-determining factor, the percentage of breaking of the linkage between any two factors is fairly constant. If the percentages between characters *a* and *b* and between *b* and *c* are known, that between *a* and *c* is either the sum or the difference of the others. The fifty or so characters in this linked group all fit into this linear arrangement. A line with the factors located upon it can be drawn, in which the distance between any two points, representing the location of factors, corresponds to the percentage of breaking of linkage between those two points. Such diagrams have been carefully constructed. For instance, the percentage of separation of the characters yellow body and white eye is 1.2, of white eye and bifid wing 3.5, and of yellow body and bifid wing 4.7, or the sum of the other two.

As stated, this linear arrangement, in which the distance between any two factors is proportional to the percentage of separation of the characters, is fairly consistent but not wholly so. There is a tendency for the high values calculated from the sums of two components to be somewhat higher than the actual ones. The suggested explanations will be given later.

It is perfectly natural to suppose that this linear arrangement on the basis of percentage of separation of the factors in breeding may represent an actual linear arrangement within the chromosomes. This necessitates the postulate that the chromatin granules as they pass from the resting stage preceding a cell division always arrange themselves in the same definite, fixed order when they form a chromosome. It is only recently that there has been any cytological evidence bearing on this point.

Assuming that the granules actually do lie in a fixed order, to explain the facts of the breaking of linkage it is necessary to discover a mechanism by which the granules of one chromosome may be exchanged for those of its mate as the two lie side by side at the beginning of the maturation divisions of the egg.

It will be remembered that the two chromosomes which lie side by side in this manner come from separate parents. It was supposed that they always separate as units, but it has been known for some years that they frequently twist around each other, and may indeed seem to fuse at the point where one

crosses the other. It was supposed until recently that when the members of the pair separate to travel toward opposite poles they have undergone no exchange of material. If, however, there is a real union at the nodes it is perfectly probable that parts of the two may be interchanged. For instance, if we take the case of a single twist, one end of chromosome *A* may be united with the other end of chromosome *B*, on the one side of the figure, with the reverse relation, on the other side. A factor located near one end of a chromosome is thus separated from one located near the other end. It is obvious that the nearer together two factors are within a chromosome the less chance there is that the crossing over of a twist will come between them. The percentage of such separation of characters in experimental breeding may then be taken as a measure of the distance apart of the factors in the chromosome assuming that the "twistability" of the chromosome is the same at all points. It is further natural to assume that the chromomeres are the seats of these separate factors.

It has already been mentioned that the percentage of separation between *a* and *c* tends to be somewhat less than the sum of the percentages between *a* and *b* and between *b* and *c*. This may be explained on the supposition that two twists sometimes take place between the more widely separated points and the result of two twists is the same as that of no twist as far as the factors in question are concerned. The percentage is therefore decreased for the greater distances. That such double crossing over occurs has been proved in other ways.

The fact of twisting of chromosomes has actually been observed in a number of cases, but the behavior of the chromomeres is hard to make out with any degree of certainty because they are near the limit of visibility even under the highest powers of the microscope. It is impossible, therefore, at present, to confirm by actual observation of the hereditary substance the hypothesis of exchange of material between the chromosomes in the manner just described. On the whole, the general evidence is favorable to the view, but there are still a number of difficulties. One of these has to do with the fact that crossing over takes place only in the female.

As far as the sex linked characters are concerned there is no difficulty, because in the male the sex chromosome either has no mate or has one with which no crossing over can occur. It is only in the female that crossing over is possible and the cytological evidence, therefore, is in agreement with the data of experimental breeding. With regard to the characters that

are not sex linked, there is, however, no satisfactory cytological explanation of the difference between male and female. A careful study is now being made by several workers particularly of the more difficult female material, and it is to be hoped that some definite conclusion may be reached on this important point.

Castle has recently attempted to show that a closer approximation to the data of percentage relations may be obtained by supposing that the factors do not have a strict linear arrangement. The hypothesis has also to meet difficulties due to the fact that the percentage of crossing over may be changed in various ways, though none of these changes affects the linear arrangement.

On the whole, the chromomere hypothesis still lacks some important elements before it can compare with the chromosome hypothesis in degree of demonstration. It has, however, already led to a number of very important discoveries regarding the method of inheritance and can therefore be said to have justified itself.

Conclusion

By correlating the data from experimental breeding with those from the microscopical examination of the germ cells, the biologist has been able to demonstrate the existence of a mechanism which explains many things about the manner in which characters are transmitted from generation to generation. To a large extent, the model is based upon the action of parts actually visible and clear to all observers. As the limit of visibility under the highest powers of the microscope is approached, as in the case of the chromomeres, there is however, a difference of opinion as to the facts. The imagination then comes into play and it may be that some of the structures figured are purely creatures of the imagination, just as the mannikins of the seventeenth-century observers were. This probability, however, does not invalidate the clearly demonstrated features of the model.

Having this model in mind, the biologist can plan manipulations similar to those which he would practise upon a machine large enough for the parts to be handled directly. A very great many discoveries of importance in the field of heredity have been the results of such imaginary manipulations.

But the biologist is not content to stop with the visible elements of his model. The cell, the nucleus and cytoplasm, the chromosomes and perhaps the chromomeres, are definite parts of a mechanical model that works in practise. But why do the

chromomeres act as they do? Why is one different in its action from others? The biologist now becomes a philosopher. He tries to picture to himself further extensions of the model he has built so far, on the basis of demonstrable data. On the basis of past achievement he is inclined to believe that the chromomeres differ in their action because they differ in structure and related function. Therefore they are not the ultimate units of the structure. It is natural for him to try to connect them with the units of the physicist and chemist, the so-called chemical elements and the electrons. But the gap between his model and that of the physicist is still too great to enable him to make any considerable use of the latter. The method of procedure in the two cases is much the same, but perhaps the construction of the physicist is the more speculative one.

As I have said, when the biologist comes to the last demonstrable elements of his model he is inclined to suppose that in the future it may be indefinitely extended by the same method of procedure which he has previously pursued and that it may at some time be linked up with the units of the physicists. Curiously enough, several eminent physicists have strongly contested such a possibility. They seem much more inclined than are the biologists to put a limit upon such an extension and to assume the existence of non-material factors. Perhaps they do not realize what the biologist knows all too well, namely, the hopeless sterility in the past of all such ideas of non-material factors. The devising of non-material factors is an interesting mental exercise. Men have been busy with it from the earliest times. But there is no indication that any considerable advance in our knowledge of organisms has been obtained in that way. Of course this does not prove that the truth may not lie in that direction. Since the great majority of people find satisfaction in postulating such non-material forces in explanation of observed activities, it is perhaps well that the small minority who find some satisfaction in constructing their incomplete mechanical models will never be able to make their models complete. For no matter how far such models are extended they will always finally end up in units, which will furnish opportunity for the ever-ready remark, "Aha! there you have something which your model does not explain. Must you not assume a non-material factor to explain *its* action?" The only answer that can be given is the one already stated—that as time goes on more and more of the activities of living things can be pictured in terms of demonstrable mechanical models.

A SIMPLIFIED MUSICAL NOTATION

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With an Introduction

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INTRODUCTION

The complications of musical notation have been for generations the despair of students, teachers, theorists, and executants. Difficulties attendant on reading music in various keys and clefs, in correctly performing elaborate groups of chromatic notes, and in selecting, for composition, one enharmonic use as being more suitable than another—these, with other difficulties, have not only retarded the progress of musical education, but have actually prevented multitudes from coming into direct association with music. It is indeed paradoxical that music, which, of all the arts, makes the most instant appeal, should have so hedged itself about with complicated and confusing symbols. By a process simple, logical, and musically sound, Professor Huntington has destroyed the terrors of chromatic notation.

Many persons reading the title of this article and observing the author to be by profession a mathematician will say, "This is probably some scientific speculation. There is no chance that our notation will be changed, so why read all this?" But open-minded and intellectually honest musicians will read these paragraphs, and will ask themselves a very different sort of question.

A. T. DAVISON

A SIMPLIFIED MUSICAL NOTATION

THE purpose of this paper is to present a new musical notation which, while retaining all the excellent features of the present notation, would, it is believed, greatly simplify the processes of reading, studying and composing musical scores.

The plan is not one of the artificial mnemonic devices of which the literature is full,[1] but is based directly on the fundamental principle of modern music, namely, the equi-tempered

[1] For a critical account, see C. F. Abdy Williams, "The Story of Notation," Scribners, 1903.

scale. This scale, introduced by J. S. Bach about two centuries ago, and now dominating all musical composition, makes use of *only twelve notes in each octave*, these twelve notes dividing the octave into twelve mathematically equal intervals, called semitones. Now, if we draw an ordinary five-line staff with one ledger line, we see that exactly twelve notes can be accommodated on the lines and spaces of such a staff. *What is then more natural than to assign one place on the staff to each of the twelve notes of the scale, thus doing away with all "sharps" and "flats," and representing every musical interval correctly to the eye as well as to the ear?* This, in brief, is precisely the plan here proposed.

The details are easily completed. We assign the notes commonly known as C, C♯ or D♭, D, etc., to the places indicated in Fig. 1.

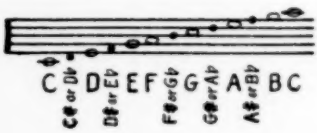



Fig. 1.

In speaking of the note "C♯ or D♭" in conversation, either name may be used indifferently, since the two names (in the modern temperament) are simply synonyms for the same note. But in reading or writing a score, on the proposed plan, this single note is represented by a single degree of the staff, unmodified by any sharps or flats. In other words, every note used in modern music has one and only one place on the staff, and every degree of the staff represents one and only one note.

Moreover, the proposed representation of every octave is simply a repetition of every other octave, so that no "clefs" (treble, 𝄞; base, 𝄢; tenor, 𝄡; etc.) are required. The successive octaves from low bass to high treble may conveniently be numbered consecutively from 1 to 8, "middle C" falling between the fourth and fifth octaves, as shown in Fig. 2.

This Fig. 2 illustrates how clearly the range of pitch of any musical instrument can be exhibited in the new notation. The striking contrast between the old method and the new in this respect is shown in Fig. 3, the data for which are taken from Cecil Forsyth's "Orchestration" (Macmillan, 1914).

The chief merit of the new plan is that *every musical interval, and hence the structure of every musical chord, is repre-*

sented correctly to the eye by the relative distances between the notes on the staff.

For example, the intervals in Fig. 4*a* and Fig. 4*b*, which look so different in the old notation, are really equal intervals, represented in the new notation as in Fig. 4*c*.

This direct correspondence between the ear-interval and the

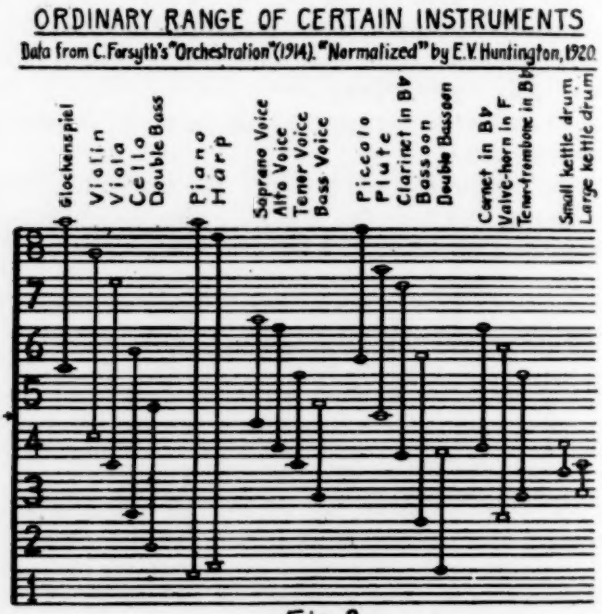


Fig. 2.

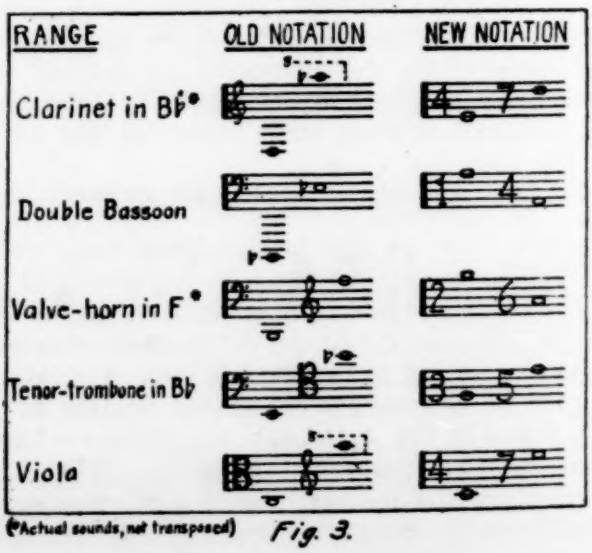



Fig. 3.

eye-interval would seem to be a great advantage in sight-reading, both for singers and for players. In particular, the labor of *transposition from one key to another* is greatly simplified in the new plan; for, since the relative position of the notes is unchanged, the process of transposition may be regarded as

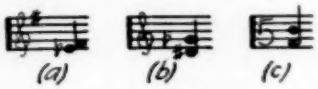


Fig. 4.

merely a shifting of the background of lines and spaces, with no thought of key-signatures, accidentals, etc., that are now so troublesome. A similar remark applies to the transposed scales which are often used in writing for special instruments, to facilitate fingering.

These are all the points that need be mentioned in order to make the scheme of the new or "normalized" notation clear. No change is made in the present mode of indicating the duration of a note (quarters, ♩; eighths, ♪; etc.) or the time (3/4 time, 4/4 time, etc.) or in the present symbols indicating expression (f, pp., pedal, etc.). The important change is the abolition of the "sharps" and "flats" which have been the trial and perplexity of pupils for so many generations. These sharps and flats, whether occurring as accidentals, or in the key-signature, may now be recognized as merely the result of an attempt, historically explicable, but necessarily unsuccessful, to crowd twelve notes into seven degrees of the staff, instead of providing each note with its own place.

In order to show the great simplification that the new notation would bring with it, a few bars from a complicated modern score[2] are here given in both the old and the new notations (Fig. 5). A further illustration is given in Figure 7.

It will be observed that much vertical space required in the old notation to allow for ledger lines between the bass and treble staves is saved in the new notation; also, some lateral space required for accidentals may be saved, without danger of crowding the notes. Hence, in spite of what one might expect when eight degrees of staff are expanded into twelve, the total space required on the page is only slightly increased by the new plan—certainly not more than twenty per cent. This slight objection would appear to be much more than offset by the advantages secured.

Moreover, in the case of band music, where condensation is

[2] Maurice Ravel, "Valses nobles et sentimentales," I, page 3; A. Durand & Fils, Editeurs, 1911.

Valses nobles & sentimentales. I.

A. Durand & Fils, Éditeurs, 1911. Maurice Ravel.
(D. & F. 8247) Passage from page 3.

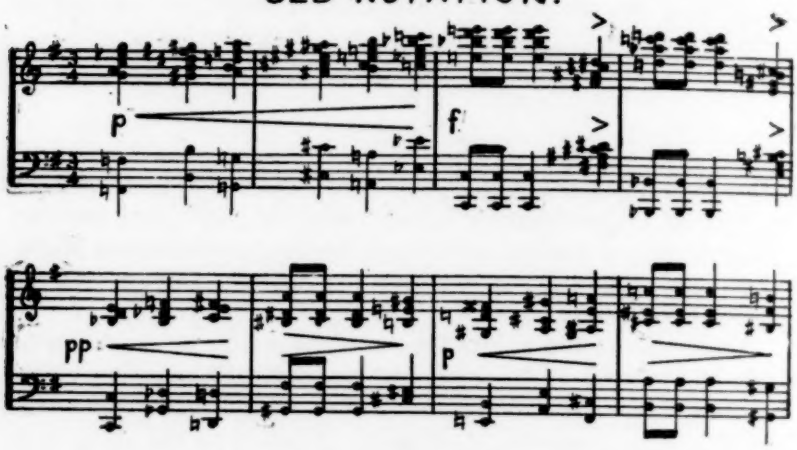
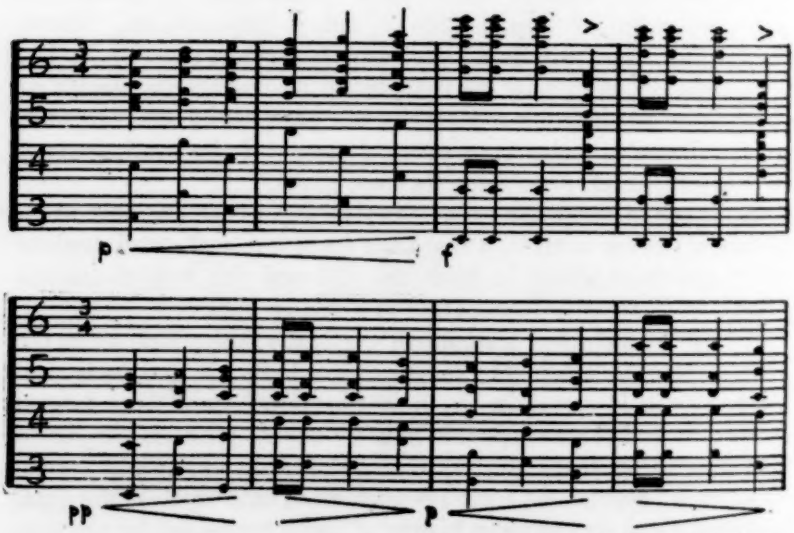
OLD NOTATION.

NEW NOTATION.

"Normalized" by E.V. Huntington, 1920.

Fig. 5.

especially desirable, the score for each instrument can, by simple devices, be compressed into a single staff.

What has been said so far has had reference to the reading of a musical score by the performer.

It remains to point out the effect of the new plan on the problems of teaching and analysis.

For purposes of elementary teaching there would seem to be great advantages in the principle of "one sound, one symbol." To avoid rhythmic complications in scale singing, however, the names of the notes should be monosyllabic. It may be desirable, therefore, to call the twelve notes of the scale by the last twelve letters of the alphabet, pronounced as follows:

O P Q, R S T; U V W, X Y Z
Oh Pee Que, Are Ess Tee; You Vee Dub, Ek Eye Zee.

The scale of C major would then be sung as

O — Q — S T — V — X — Z O

or, if preferred, the "do, re, mi" syllables could be used with fixed pitch, as in the present French schools:

do — re — mi fa — so — la — ti do

The details of such matters must of course be left to the teachers.

For purpose of analysis, the present names, "C," "C ♯ or D ♭," "D," etc., may of course be retained if preferred.

It is on the side of analysis that the only serious theoretical objections to the new plan are likely to be raised.

For one thing, the guidance to key-changes which accidentals in the present scores now provide would be lacking in the new plan; again, the fine distinctions known as enharmonic changes would cease to have any significance.

In reply to these objections, it may be said that whatever is actually present in the music as heard by the ear is faithfully reproduced in the new notation as seen by the eye. Hence it follows that the new notation omits nothing which is really essential for the analysis of the music as sound. *All that it discourages is an analysis of the symbolism of an obsolete notation.*[3] As Grove's Dictionary states, all our present rules for notation are based on the old Mean-tone temperament which made a real distinction between C♯ and D♭. They do not apply to the modern equal temperament in which these two symbols represent exactly the same sound. Now what the new notation does is to register accurately the sounds which are actually heard to-day. Any desired analysis of the relations between

[3] As a matter of fact there are no "rules" for chromatic notation. Even as early as Beethoven one finds the chromatic scale variously notated in the same composition. The question of the employment of C♯ or D♭ is usually a matter left to the whim of the composer.

those sounds can therefore be carried on entirely adequately in the new notation.

Moreover, the analysis of the relations between the actual sounds would be really easier in the new notation than in the old. For, in the new notation, on account of the direct correspondence between the ear-interval and the eye-interval, the structure of the chords that are being analyzed may be immediately recognized by their geometric "shape." In fact, a beginner might have bits of celluloid or tracing paper, marked with certain standard configurations, to use as a sort of touchstone to apply to any chord he might wish to examine.

Fig. 6.

Finally, it should be noted that any composer who desires to record the key of any composition can do so more readily in the new notation than in the old. Thus, a "key-signature," though not at all necessary, may be indicated, at any point, by simply noting the fundamental chord of the key, as in Fig. 6.[4]

The supposed objections are thus seen to be more apparent than real. In fact, the new notation might well lead to a new point of view in analysis, a point of view in which all questions of mere "spelling" would be relegated to the background, the entire attention being directed to the study of the actual sounds.

It is not the writer's purpose to discuss at this time the practical difficulties in the way of getting the proposed plan adopted. One need have no illusions as to the seriousness of these difficulties. The first essential would be, of course, to secure the publication of a great collection of standard and school music in the new notation. If this could be done on a large scale, many teachers and pupils would doubtless be glad to avail themselves of the "normalized" scores, the use of which might easily save a large part of the time and expense now required for an elementary musical training. New editions of standard works are constantly being published; it is not impossible that a decisive number of these new issues might

[4] By the addition of an occasional single letter (Ellis's "duodenal"), the new notation can even be made to indicate the notes required for "just intonation" with complete accuracy. A discussion of this phase of the subject is reserved for another occasion.

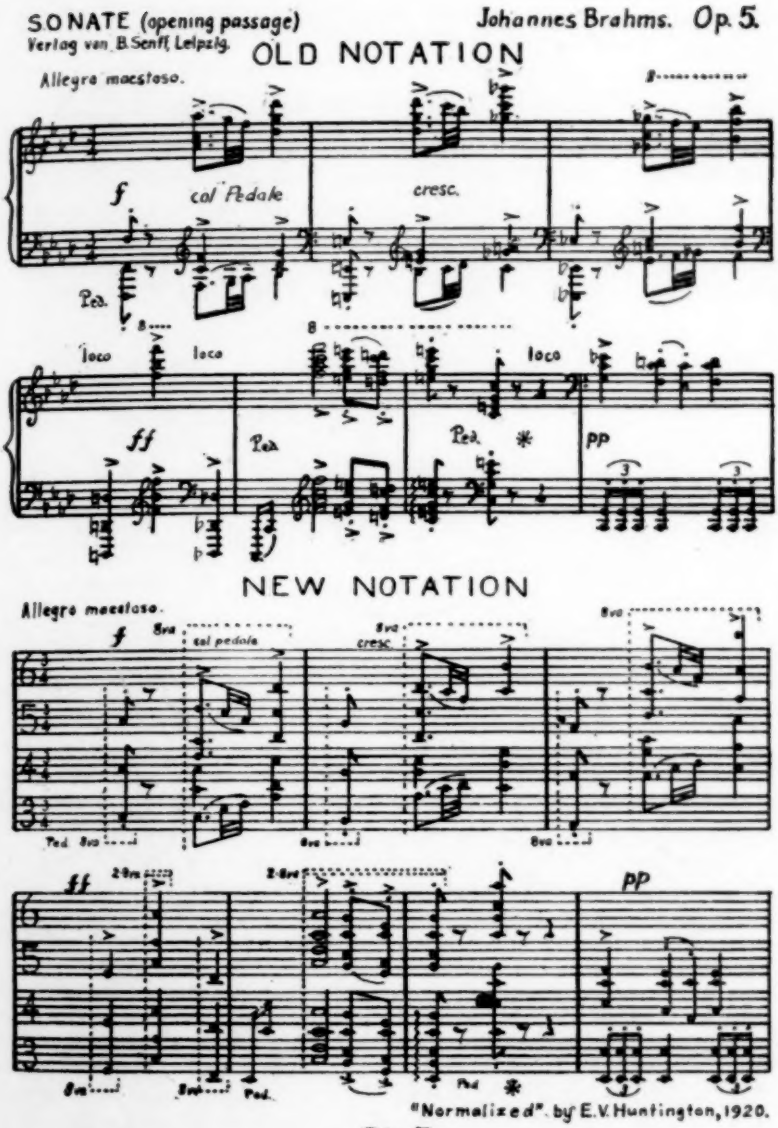



Fig. 7.

be published in the "normalized" notation. Few steps would do more, in the long run, to encourage the practise, by the people at large, of the art of musical expression.

THE PROGRESS OF SCIENCE

THE FOREIGN BORN AND NEGRO POPULATION OF THE UNITED STATES

THE Bureau of the Census is making public the population of the states and of cities according to the enumeration of the fourteenth census taken in April last. In view of the disturbances due to the war, the detailed study of the composition and distribution of the population will be of special interest, and

THE TOTAL POPULATION AND ITS ELEMENTS AT EACH CENSUS: 1850-1910

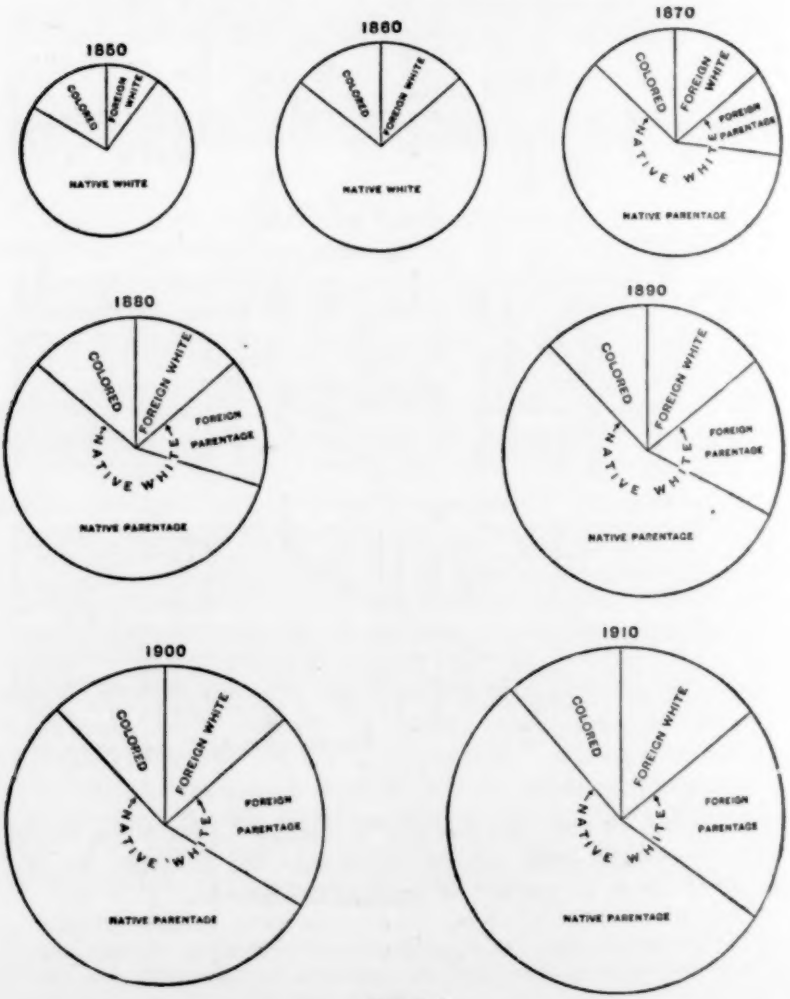


FIG. 1.

PER CENT OF FOREIGN-BORN WHITES AND NATIVE WHITES OF FOREIGN OR MIXED PARENTAGE COMBINED IN THE TOTAL POPULATION, BY STATES: 1910

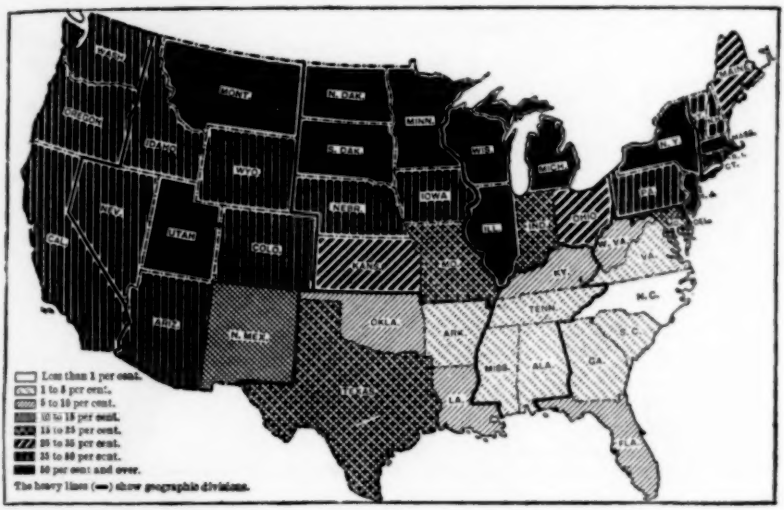

Less than 1 per cent.
1 to 5 per cent.
5 to 10 per cent.
10 to 15 per cent.
15 to 25 per cent.
25 to 35 per cent.
35 to 50 per cent.
50 per cent and over.
The heavy lines (—) show geographic divisions.

FIG. 2.

it is to be hoped that the compilation and publication of the results will be completed without delay. In the meanwhile it may be worth while to give some figures for the census of 1910, taken from the Statistical Atlas published by the Bureau of the Census in 1914.

In Fig. 1 the population of the United States is represented by circles, proportionate to the number returned at each census, from 1850 to 1910, the divisions of the circle indicating the proportion of the population in each of the principal classes. The great increase in the foreign element, including both foreign born and the native of foreign parentage, is brought out very clearly. The proportion of colored population is practically the same at each enumeration, but the proportion of native white of native parentage has steadily decreased.

Fig. 2 indicates, in eight groups, by the character of the shading, the percentage of foreign-born whites and native whites of foreign or mixed parentage combined in the total population in 1910. The solid black, indicating 50 per cent. or more, covers 13 states, while the next groups, 35 to 50 per cent., also covers 13 states, and indicates that for 26 states 35 per cent. or more of the population is of foreign birth or parentage. These 26 states have 53.3 per cent. of the total population of the United States. The state with the lowest percentage is North Carolina, which has less than 1 per cent. All the states of the South Atlantic and East South Central divisions, except Delaware, Maryland, West Virginia, Florida, and Kentucky, also the District of Columbia, have less than 5 per cent. of the foreign-born element in their population.

Fig. 3 presents, by states, the per cent. distribution of the negroes in 1910, in seven groups, shaded as indicated in the legend. Mississippi and South Carolina have the highest per cent. of negroes and are the

PER CENT OF NEGROES IN TOTAL POPULATION, BY STATES: 1910

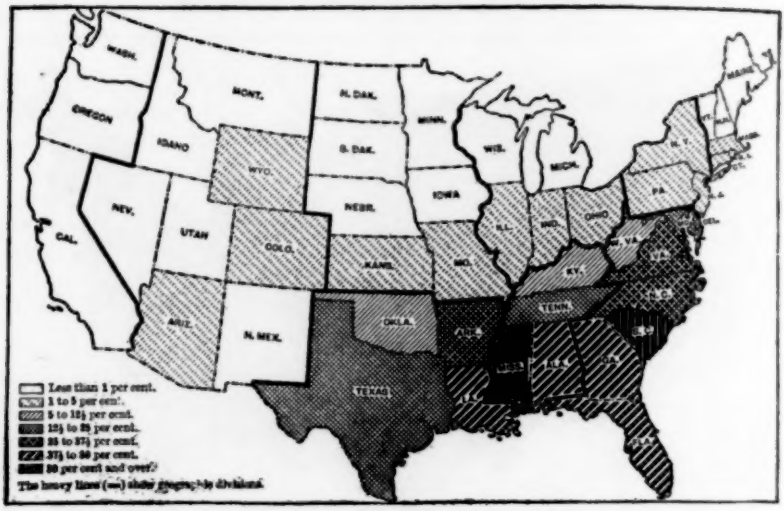


FIG. 3.

only states with more than 50 per cent. of their population negroes. South Carolina had a larger proportion of negro population than any other state at each census from 1790 to 1890, but in 1900 the number of negroes in Mississippi had increased to 58.5 per cent., while in South Carolina the per cent. had fallen to 58.4. In 1910 Mississippi had the highest percentage, 56.2, and South Carolina was second, with 55.2.

PROPORTION OF MALES TO FEMALES IN THE TOTAL POPULATION, BY STATES: 1910

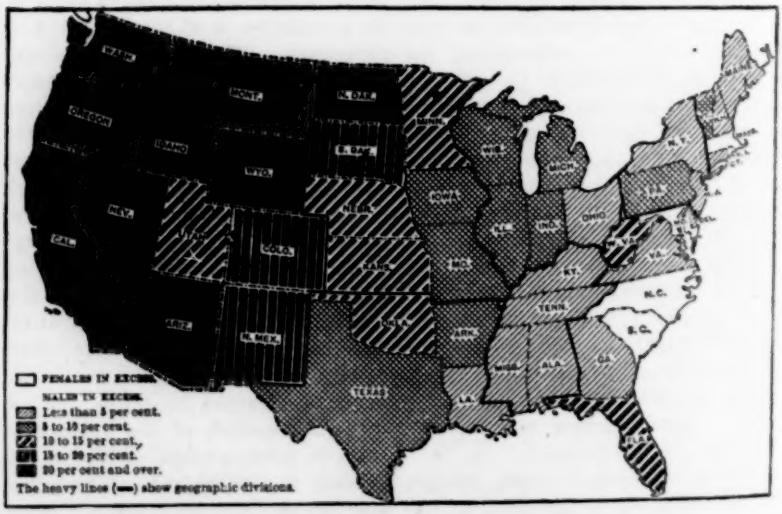


FIG. 4.

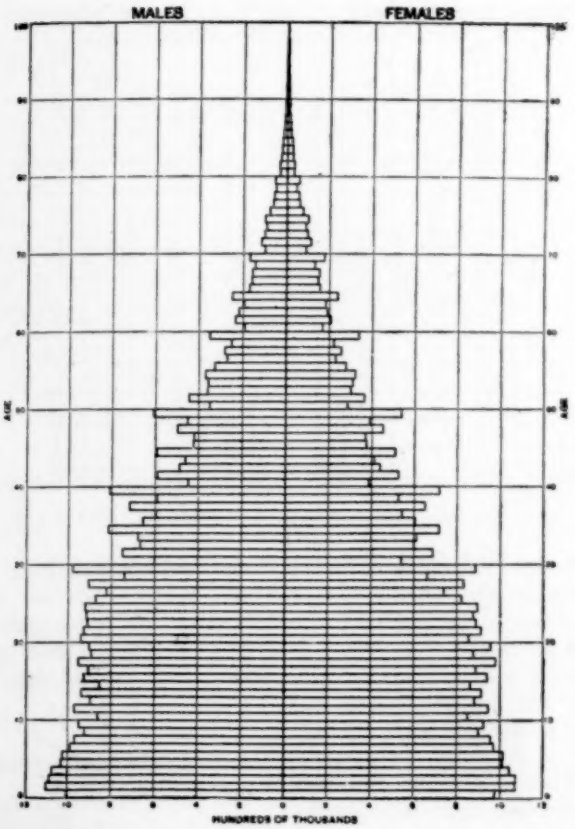


FIG. 5.

DISTRIBUTION OF THE POPULATION BY SEX AND AGE

Fig. 4 indicates the proportion of males to females in the total population at the thirteenth census, by states. The females are in excess in Massachusetts, Rhode Island, Maryland, District of Columbia, North Carolina, and South Carolina. In 1910 the states having the greatest proportion of males to females were Nevada, with 179.2, Wyoming with 168.8, and Montana with 152.1 males to each 100 females. The proportion for the United States is 106 males to each 100 females. The excess of males is due principally to the large foreign immigration, in which the males largely outnumber the females. The map brings out the fact that no geographic division east of the Mississippi River had, in 1910, more than 106 males to 100 females, the United States average, but in all of the western divisions the proportion is much higher, the Pacific division reaching a total of 129 males to 100 females. This is due to the migration of the native male population from the eastern states to California, Oregon, and Washington. The sections which have been recently settled in that part of the country give more opportunity for the labor of men than of women.

Distribution by age and sex of the total population by single years of

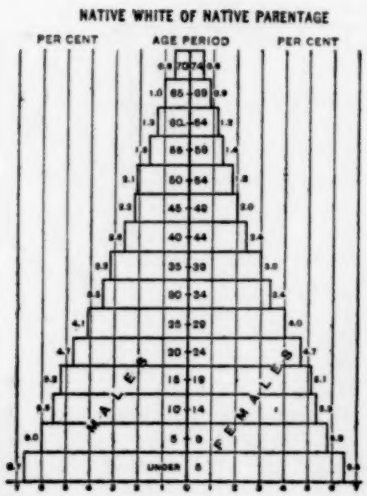


FIG. 6.

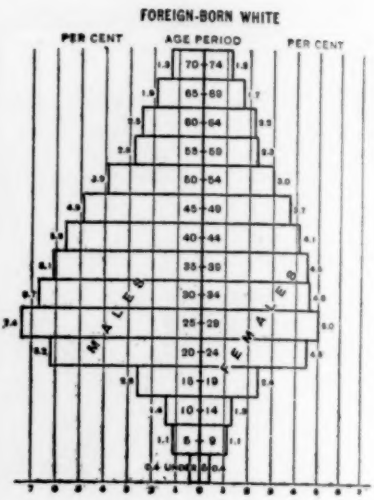


FIG. 7.

age, as shown in Fig. 5, presents very strikingly the irregularity in the proportion of the ages of the population as returned in 1910. A normal diagram should form a pyramid, each bar representing an age period being smaller than the one below it. The sexes are nearly equally divided, but the abnormal length of the bars, especially for the periods ending in zero or in 5, stand out in the diagram. Many more individuals say they are thirty years old than twenty-nine or thirty-one. The fact that fewer children are reported in the first year of life than in each of the four subsequent years indicates the defects or difficulties in the way of taking a census.

The extent to which the age and sex distribution of the population is influenced by immigration is shown in Figs. 6 and 7. Among those arriving from foreign countries the men greatly exceed the women and there are comparatively few children. Families are the most desirable class of immigrants and the laws should favor them rather than discriminate against them as is now the case.

SCIENTIFIC ITEMS

WE regret to record the death of Sir Norman Lockyer, director of the London Solar Physics Observatory and for fifty years editor of *Nature*.

CAMBRIDGE UNIVERSITY has conferred the degree of doctor of laws on Dr. John J. Abel, professor of pharmacology at the Johns Hopkins Medical School, and on Dr. Harvey Cushing, professor of surgery in Harvard University.—Dr. William W. Keen, professor emeritus of surgery at the Jefferson Medical College, president of the International Surgical Society, recently in conference at Paris, presided at the opening sessions.